Project Status Report

High End Computing Capability
Strategic Capabilities Assets Program

September 10, 2018

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Expansion Brings Electra Supercomputer to 6.55 Petaflops

- HECC augmented the Electra system with the first of two expansions, each with two E-Cells. These two HPE E-Cells bring the system's theoretical peak performance to 6.55 petaflops (PF). One E-Cell (288 nodes) was purchased for ARMD and the other had 34 nodes purchased for the ARC System Analysis Office (Code AA). The remaining 254 nodes are for general HECC use.
- The 576 compute nodes were integrated live into Electra without impacting users' running jobs. The expansion provides a 30% increase in Standard Billing Units (SBUs) delivered by the system.
- The deployment of the two E-Cells, from receipt of the equipment to production, was completed in less than 2.5 weeks.
- The second expansion, planned for release to users in October, will bring Electra to its full capacity, and raise the theoretical peak to 8.32 petaflops peak—surpassing Pleiades (7.24 PF peak performance).

Mission Impact: To meet NASA's continuously increasing requirements for high-performance computing, HECC must regularly and significantly augment the supercomputing resources provided for agency missions.

The Electra supercomputer is configured with 1,152 Broadwell nodes and 1,728 Skylake nodes in two modular containers, with a combined Power Utilization Efficiency (PUE) rating of approximately 1.03—well below the computing industry standard of 1.8 PUE.

POCs: Bob Ciotti, bob.ciotti@nasa.gov, (650) 604-4408, NASA Advanced Supercomputing (NAS) Division;
Davin Chan, davin.chan@nasa.gov, (650) 604-3613, NAS Division, ASRC

Modular Supercomputing Facility's Second Cooling Loop Put into Service

- With the addition of the two HPE E-Cells to Electra (see slide 2), a second, existing cooling loop was put into service in the MSF.
  - For the initial four E-Cell installation, only the cooling loop in the front half of the module was utilized.
- The HECC Facilities team, in collaboration with HPE, filled the second cooling loop with a water/glycol mix and readjusted the cooling system's valves to engage the second loop.
- The second loop was successfully mixed into the first loop without disrupting operation of the existing Electra E-Cells.
- Now that the second cooling loop is functional, the MSF provides cooling to the two new E-Cells, and will be prepared for the installation of two more E-Cells, which will bring the MSF to its maximum capacity of eight E-Cells.

Mission Impact: Increasing the Modular Supercomputing Facility's cooling capacity allows for an increase in computing power to the Electra supercomputer.

The two new E-Cells installed in Modular Supercomputing Facility, with the second cooling loop piping shown above the E-Cells.

POCs: Chris Tanner, christopher.tanner@nasa.gov, 650-604-6754, NASA Advanced Supercomputing Division, ASRC

Modular Supercomputing Facility Saves Energy and Money

- The MSF's Power Usage Effectiveness (PUE) rating for FY18 Q3 was 1.027—reported averages for data centers around the world range from 1.8–2.5 PUE.
  - PUE, an established metric for computer center power efficiency is calculated as the (Total Facility Power) ÷ (IT Systems Power).
  - In comparison, the FY18 Q3 PUE for the primary HECC facility in Building N258 was 1.34; average for other NASA data centers (not including the HECC assets) is approximately 1.9.
- The MSF rolling annual PUE is also 1.027.
- The total power draw averages 860 kW with only 22 kW used for facility cooling.
- The MSF does not use any mechanical refrigeration, saving energy compared to traditional data centers.
- Installing Electra in the MSF saves $175K per year in power versus installing the system in the main NAS facility.

Mission Impact: The Modular Supercomputing Facility provides additional compute resources for users in an energy efficient facility. The energy savings provided by the MSF allows for more HECC funds to be spent on compute and storage resources.

The Modular Supercomputing Facility at NASA Ames Research Center comprises two modules housing the Electra supercomputer. The facility provides cooling to Electra without the use of any mechanical refrigeration, saving NASA about $175K per year in energy costs.

POC: Chris Tanner, christopher.tanner@nasa.gov, 650-604-6754, NASA Advanced Supercomputing Division, ASRC

NAS Facility Expansion Progress Status

- The HECC Facilities team, in collaboration with NASA Ames Code JCE and vendors Jacobs, Tri-Technic, and HPE, continued progress on the NAS Facility Expansion (NFE) project.
- Construction progress includes:
  - Completed the power duct bank between the N225B sub-station and the NFE site.
  - Completed the communication duct bank between building N258 and the NFE Site.
  - Installed the 30-MW transformer and "dead-end steel structure" in the N225B sub-station.
  - Received the 115-kV circuit breaker and 35-kV feeder conductors.
  - Completed the aggregate pad to support the NFE concrete mat slab.
  - Completed ground work and curbs for the access road that encircles aggregate pad.
- HPE submitted a 90% design package to the NASA Ames Permit Board. Comments received will be incorporated into the package and resubmitted in mid-September.

Mission Impact: The NAS Facility Expansion will provide the infrastructure to deliver four times the computing capacity of existing HECC resources.

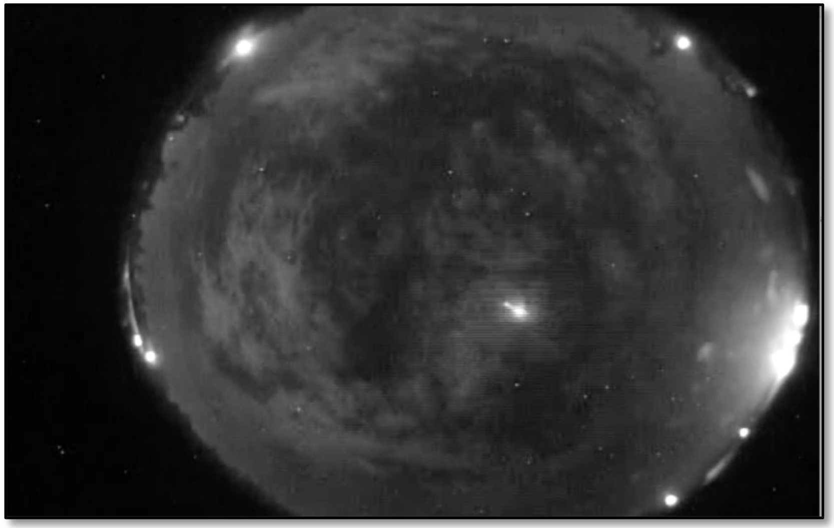
Construction crews finished assembly of the new "dead-end steel structure" used to support the 115-kilovolt feeder connections to the new 115-kV circuit breaker and 30-megawatt transformer, shown installed on the concrete foundation.

POC: Chris Tanner, christopher.tanner@nasa.gov, 650-604-6754, NASA Advanced Supercomputing Division, ASRC

Machine Learning Performance Improvement for Asteroid Threat Prediction

- HECC's data analytics experts improved the performance of a machine learning tool (TensorFlow) calculation to predict meteor characteristics based on measured light curve data.
- Computational simulations provide a vast dataset that can be used to train models and compare with observational data from an actual airburst in the Earth's atmosphere.
- The TensorFlow tool uses the simulation data to train the numerical neural network to predict asteroid characteristics, such as diameter, velocity, density, and strength.
- Initially, the computational performance of TensorFlow took close to 4 hours to complete the neural network training.
- With the HECC staff's understanding of the data and our system, a better set of parameters was chosen, and the training now finishes in 30 minutes—a 7 times speedup in terms of performance.

Mission Impact: HECC's machine learning expertise enhances NASA's capability to understand Earth-impacting asteroid characteristics and better predict the risk and potential damage from an asteroid airburst, for the Asteroid Threat Assessment Project.



Meteor flare captured by an all-sky camera at Mountain View High School in California. Camera networks record the brightness of the flare over time and are used to construct light curves for such events. Light curves provide information from which we learn about the characteristics of objects entering the Earth's atmosphere.

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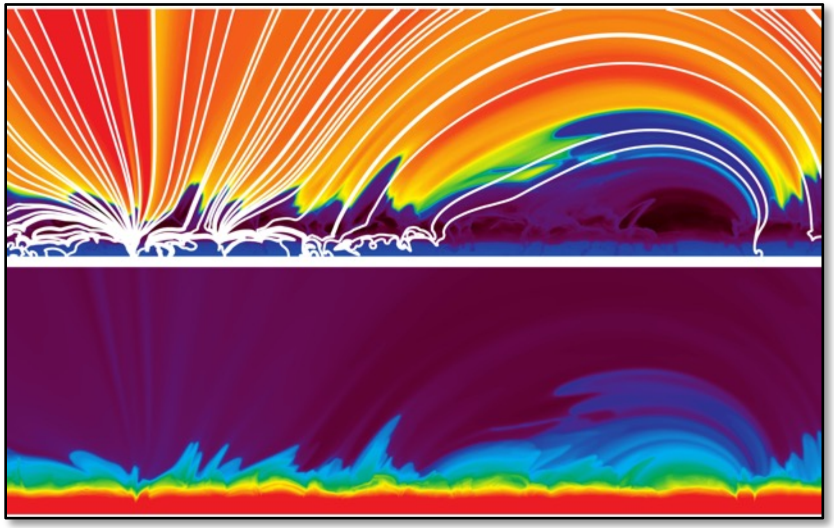
Pleiades Simulations Reveal the Formation of Spicules—the Sun's Swirling Jets*

- To better understand how the solar atmosphere is shaped and heated, and how it impacts Earth, researchers from the University of Oslo and Lockheed Martin Solar & Astrophysics Laboratory simulated a 96 x 40-megameter piece of the sun on Pleiades, at a resolution of 14 kilometers/pixel.
- By comparing the simulation results with images and spectra taken by the NASA's Interface Region Imaging Spectrograph (IRIS) observatory, the researchers were able to explain some of the mission's puzzling findings.
  - The results showed for the first time how jets of solar material, called spicules, form naturally in simulations of the sun's atmosphere, matching observations from IRIS and other observatories.
  - The simulations also helped reveal how small-scale magnetic fields can release energy and mass that impact the lower atmosphere (chromosphere), the layer of the sun that is the source of most of the ultraviolet radiation that impacts Earth's upper atmosphere.
- Modeling the complex physical processes of the sun, along with the contrasts of density, temperature, and magnetic field within its atmosphere, requires powerful HPC resources.

** HECC provided supercomputing resources and services in support of this work.*

Mission Impact: This research provides critical insight into the physical mechanisms that drive some of the solar events observed by NASA's IRIS Mission. The combination of simulations and observations is crucial to solving a fundamental puzzle in solar physics: how magnetic fields energize the atmosphere.



Side view of a simulated solar atmosphere from a 2.5-dimensional magnetohydrodynamic model, showing elongated jets of dense, cool gas ejected from the sun's surface. Top: Logarithm of temperature with overlapping magnetic field lines (white). Bottom: Logarithm of density.

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Viggo Hansteen, viggo.hansteen@astro.uio.no, +47-22856120,
University of Oslo

HECC Facility Hosts Several Visitors and Tours in August 2018

- HECC hosted 14 tour groups in August; guests learned about the agency-wide missions being supported by HECC assets, and some groups also viewed the D-Wave 2000Q quantum computer system. Visitors this month included:
  - NASA Administrator, Jim Bridenstine.
  - Members of the NASA Advisory Council (NAC).
  - NAC members from the NASA Human Exploration and Operations and Science Committees.
  - NASA Safety & Mission Assurance Team.
  - Jeff DeWitt, NASA Chief Financial Officer.
  - Members of the NASA Software Assurance Working Group.
  - Partners from the NASA Frontier Development Laboratory, including guests from Intel, Google, NVIDIA, and IBM.
  - Faculty members, United Negro College Fund.
  - Three visitors from the Israeli Consulate in San Francisco.
  - Students from the U.S. Air Force Test Pilot School.
  - Students from the Blue Marble Space Institute of Science, Young Scientist Program.
  - A group of interns from Planet Labs.

NASA Administrator Jim Bridenstine (far left) toured the NASA Advanced Supercomputing facility at NASA Ames and learned about the D-Wave quantum annealing system with (from left) Piyush Mehrotra, NAS Division Chief; Rupak Biswas, Director of Exploration Technology; Chris Henze, Data Analysis and Visualization Lead; and Eleanor Rieffel, Quantum Artificial Intelligence Lab [QuAIL] Lead) *Marco Librero, NASA/Ames*

POC: Gina Morello, gina.f.morello@nasa.gov, (650) 604-4462, NASA Advanced Supercomputing Division

Papers

- "**Replication of the Historic Record of Martian Global Dust Storm Occurrence in an Atmospheric General Circulation Model**," J. Shirley, et al., Icarus, vol. 317, published online August 1, 2018. *
https://www.sciencedirect.com/science/article/pii/S0019103518301726
- "**Age of Martian Air: Time Scales for Martian Atmospheric Transport**," D. Waugh, A. Toigo, S. Guzewich, Icarus, vol. 317, published online August 2, 2018. *
https://www.sciencedirect.com/science/article/pii/S0019103518300034
- "**Global Non-Potential Magnetic Models of the Solar Corona During the March 2015 Eclipse**," A. Yeates, et al., arXiv:1808.00785 [astro-ph.SR], August 2, 2018. *
https://arxiv.org/abs/1808.00785
- "**Comparisons of Bin and Bulk Microphysics Schemes in Simulations of Topographic Winter Precipitation with Radar and Radiometer Measurements**," M. Han, T. Matsui, T. Iguchi, Quarterly Journal of the Royal Meteorological Society, published online August 13, 2018. *
https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/qj.3393
- "**The Energy Flux Spectrum of Internal Waves Generated by Turbulent Convection**," L.-A. Couston, et al., arXiv:1808.04638 [physics.flu-dyn], August 14, 2018. *
https://arxiv.org/abs/1808.04638
- "**Gauss's Law Satisfying Energy-Conserving Semi-Implicit Particle-in-Cell Method**," Y. Chen, G. Toth, arXiv:1808.05745 [physics.comp-ph], August 17, 2018. *
https://arxiv.org/abs/1808.05745

** HECC provided supercomputing resources and services in support of this work*

Papers (cont.)

- "**Globally Distributed Energetic Neutral Atom Maps for the "Croissant" Heliosphere**," M. Kornbleuth, et al., arXiv:1808.05997 [astro-ph.SR], August 17, 2018. *
  https://arxiv.org/abs/1808.05997
- "**Prediction of Reynolds Stresses in High-Mach-Number Turbulent Boundary Layers using Physics-Informed Machine Learning**," J.-X. Wang, J. Huang, L. Duan, H. Xiao, arXiv:1808.07752 [physics.flu-dyn], August 19, 2018. *
  https://arxiv.org/abs/1808.07752
- "**A Predicted Small and Round Heliosphere**," M. Opher, A. Loeb, J. Drake, G. Toth, arXiv:1808.06611 [physics.space-ph], August 20, 2018. *
  https://arxiv.org/abs/1808.06611
- "**Multi-Species and Multi-Fluid MHD Approaches for the Study of Ionospheric Escape at Mars**," L. Regoli, et al., Journal of Geophysical Research: Space Physics, published online August 22, 2018. *
  https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2017JA025117
- "**Tracing Outflowing Metals in Simulations of Dwarf and Spiral Galaxies**," C. Christensen, et al., arXiv:1808.07872 [astro-ph.GA], August 23, 2018. *
  https://arxiv.org/abs/1808.07872
- "**Origin of Circumpolar Deep Water Intruding onto the Amundsen and Bellingshausen Sea Continental Shelves**," Y. Nakayama, D. Menemenlis, H. Zhang, M. Schodlok, E. Rignot, Nature Communications, no. 9, August 24, 2018. *
  https://www.nature.com/articles/s41467-018-05813-1

** HECC provided supercomputing resources and services in support of this work*

Papers (cont.)

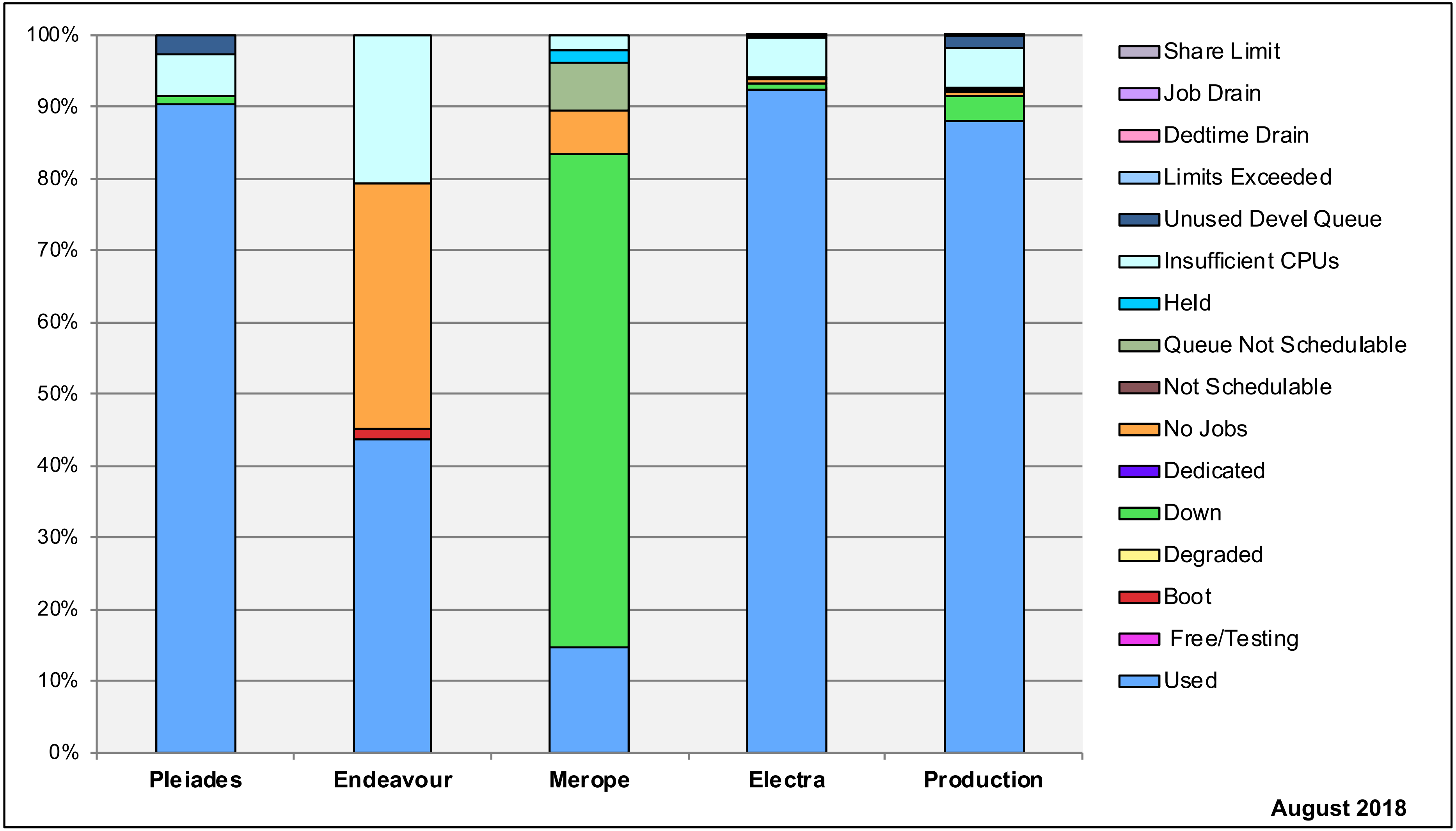
- “**Predicting the Corona for the 21 August 2017 Total Solar Eclipse**,” Z. Mikic, et al., Nature Astronomy, August 27, 2018. *
  https://www.nature.com/articles/s41550-018-0562-5
- “**Diverse Protoplanetary Disk Morphology Produced by a Jupiter-Mass Planet**,” J. Bae, P. Pinilla, T. Birnstiel, arXiv:1808.09472 [astro-ph.EP], August 28, 2018. *
  https://arxiv.org/abs/1808.09472
- “**Origin of CGM OVI in Cosmological Simulations: Redshift, Mass and Radial Dependence of Collisional and Photo Ionization**,” S. Roca-Fabrega, et al., arXiv:1808.09973 [astro-ph.GA], August 29, 2018. *
  https://arxiv.org/abs/1808.09973

** HECC provided supercomputing resources and services in support of this work*

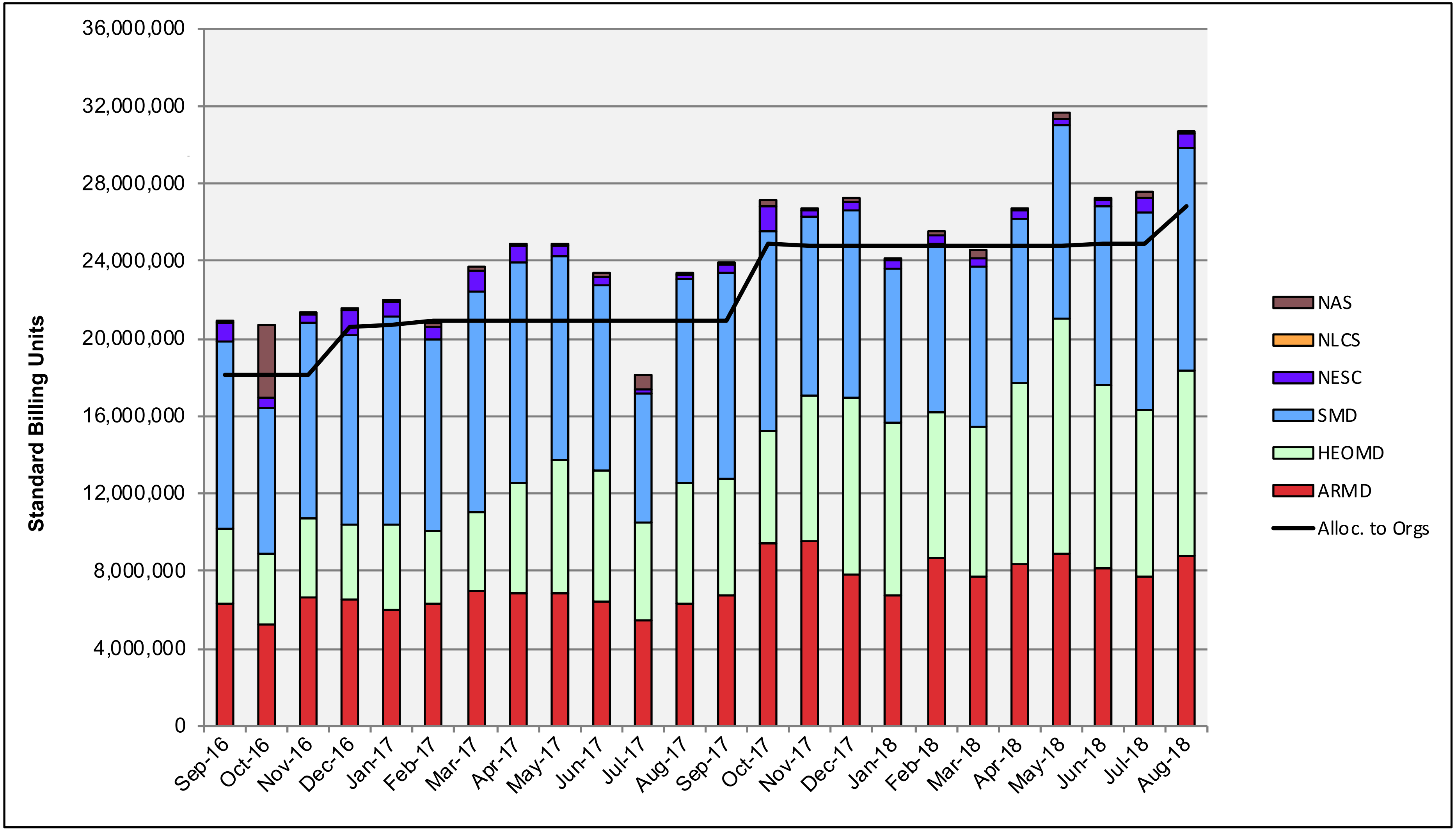
News & Events

- **240 Cubic Miles of Magma Was Just Discovered Beneath California's Supervolcano**, *Forbes*, August 16, 2018—Researchers at the United States Geological Society are actively monitoring the Long Valley supervolcano, using the Pleiades supercomputer to help decode an image of the subsurface gathered from seismic tomography data. *https://www.forbes.com/sites/trevornace/2018/08/16/a-massive-240-cubic-miles-of-magma-was-just-discovered-beneath-californias-supervolcano/#57830c4c6cb9*
- **How Scientists Predicted Corona's Appearance During Aug. 21, 2017 Total Solar Eclipse**, *NASA Press Release*, August 27, 2018-–Researchers from Predictive Science Inc. used data from NASA's Solar Dynamics Observatory and computer models to predict the appearance of the solar corona during the 2017 Total Solar Eclipse. *https://www.nasa.gov/feature/goddard/2018/how-scientists-predicted-corona-s-appearance-during-aug-21-2017-total-solar-eclipse*
- **Predicting the Sun's Corona for the Great American Solar Eclipse**, *NAS Feature Story,* August 27, 2018—Heliophysics researchers ran complex, dynamic solar models on the Pleiades supercomputer, using real-time observational data to predict the features of the solar corona prior to the 2017 Great American Solar Eclipse. *https://www.nas.nasa.gov/publications/articles/feature_solar_eclipse_PredSci.html*
- **Why Do Galaxies Start Out as Cosmic Pickles?**, *American Scientist (vol. 106, no. 5)*, September-October Issue–Researcher Joel Primack discusses how astrophysicists have been using computer models and the Pleiades supercomputer to understand the complex history of the universe. *https://www.americanscientist.org/article/why-do-galaxies-start-out-as-cosmic-pickles*

HECC Utilization



HECC Utilization Normalized to 30-Day Month



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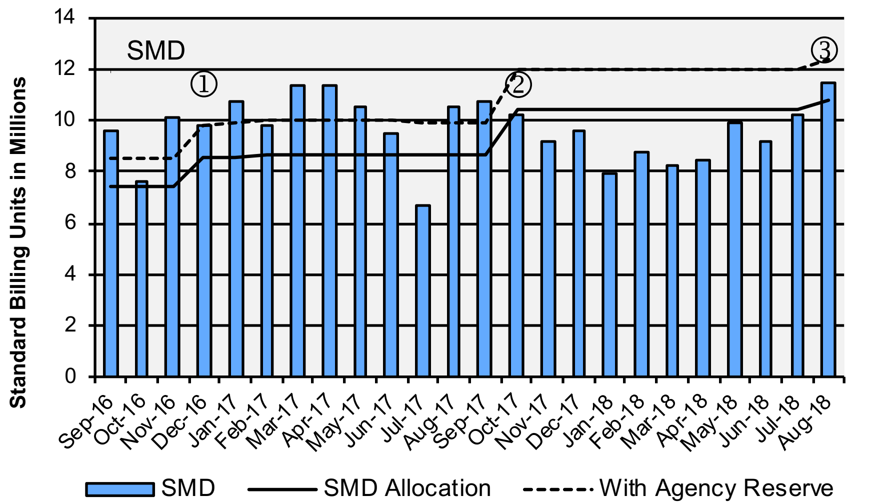
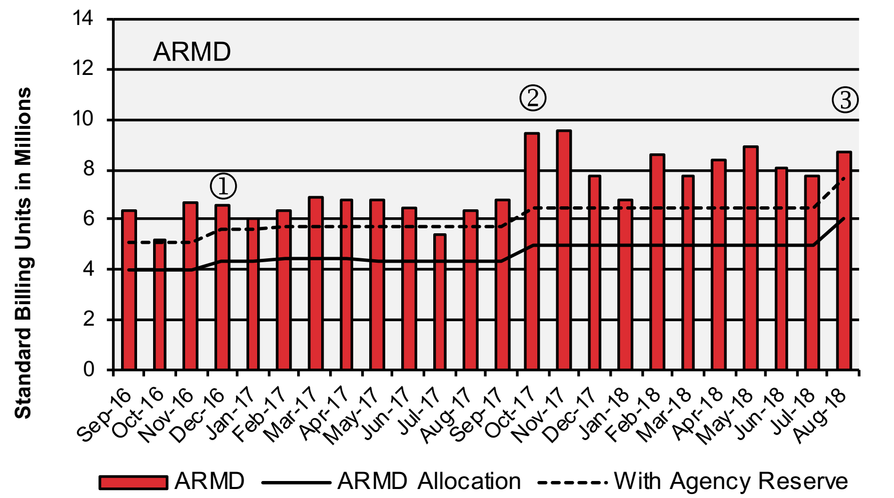
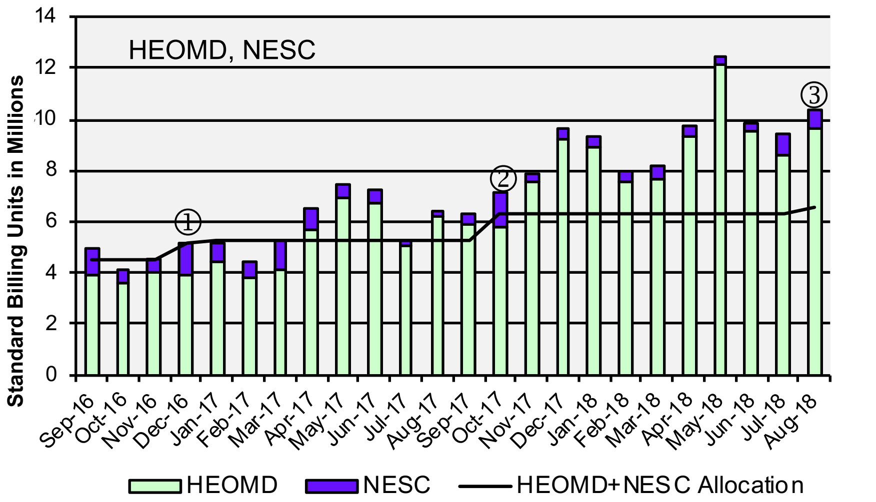




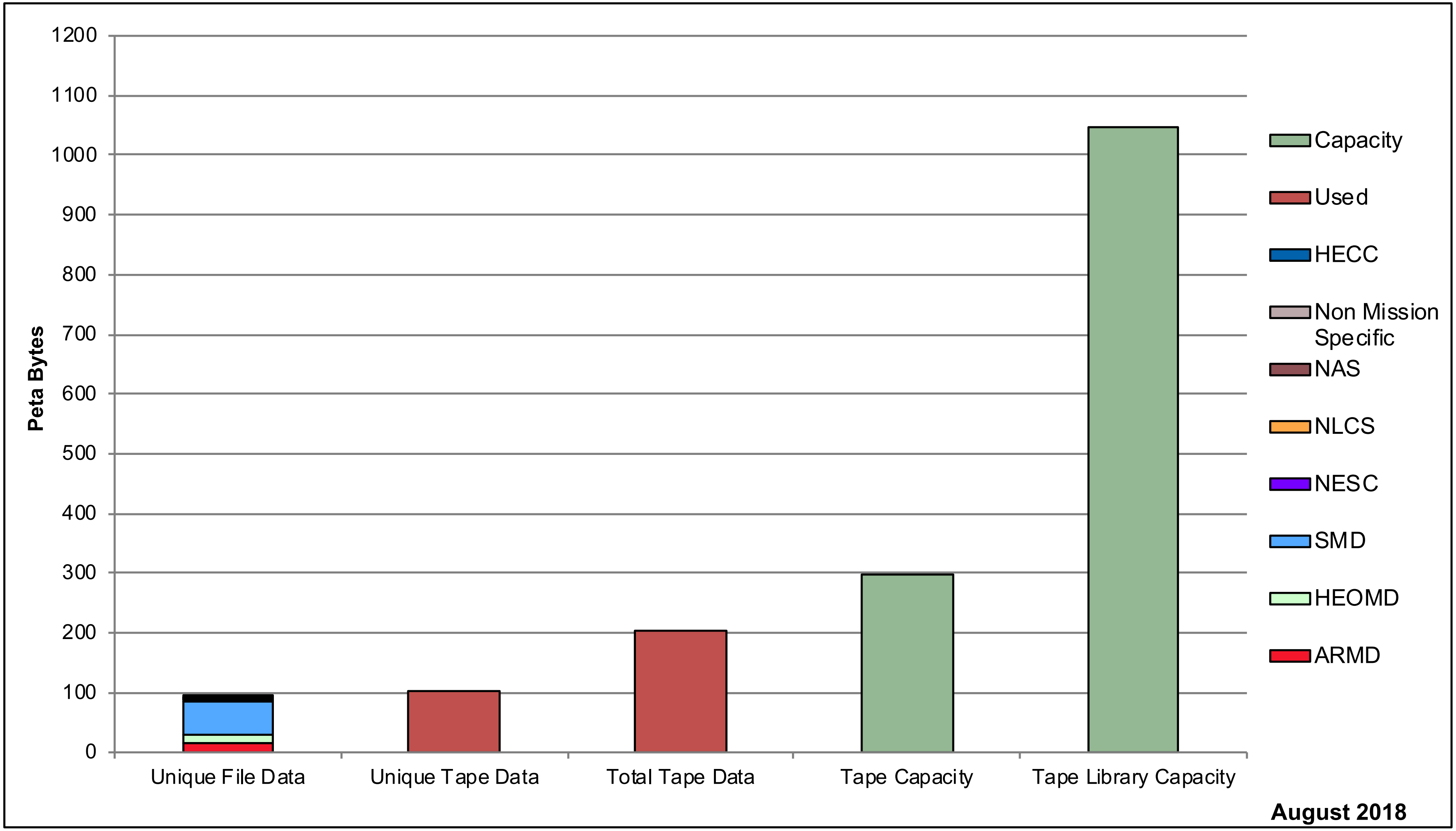


① 16 Broadwell racks added to Electra, 20 Westmere half racks added to Merope

② 4 Skylake E cells (16 D Rack Equivalence) added to Electra

③ 2 Skylake E cells (8 D Rack Equivalence) added to Electra; 1 rack was purchased by ARMD

Tape Archive Status



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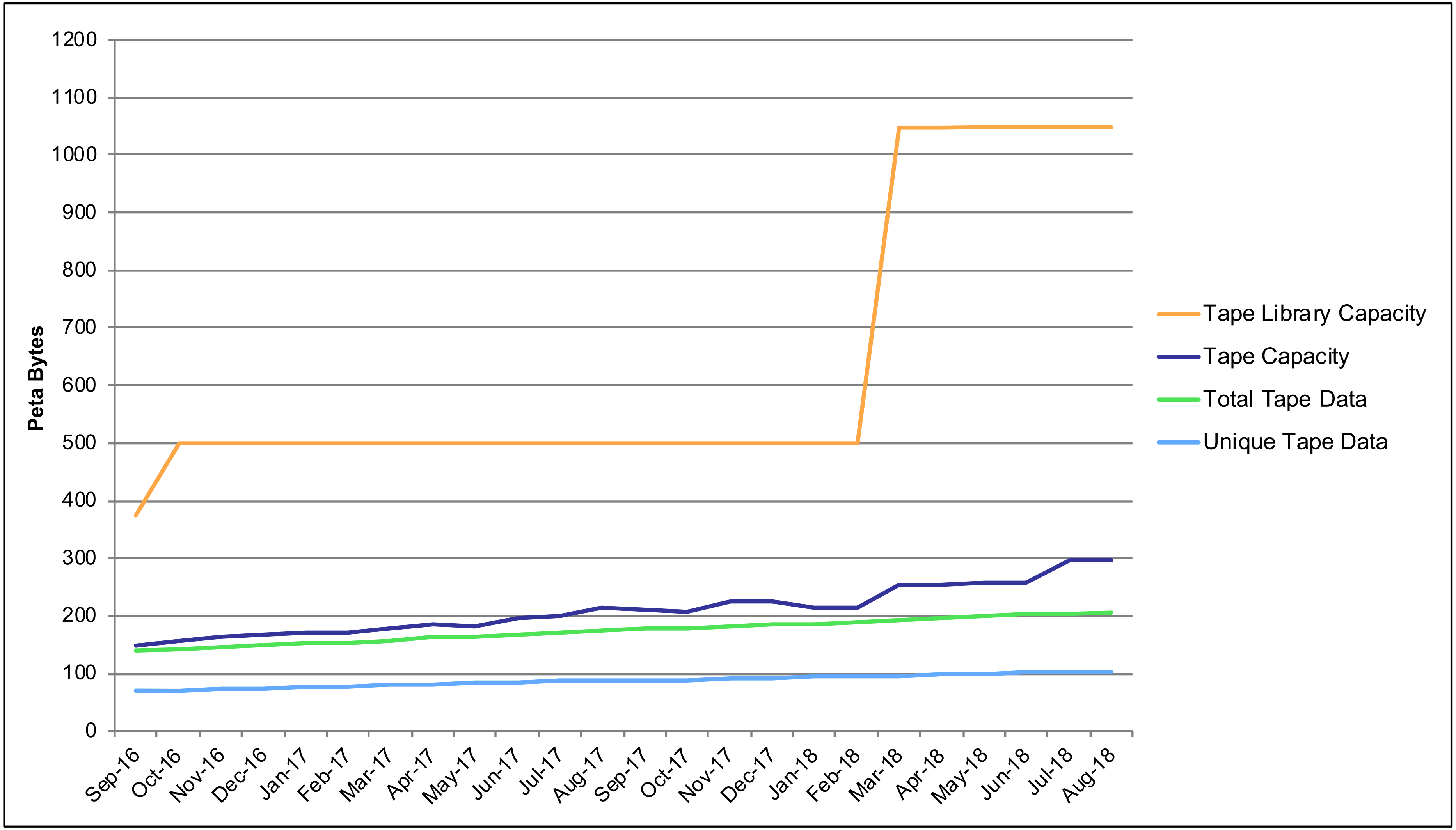
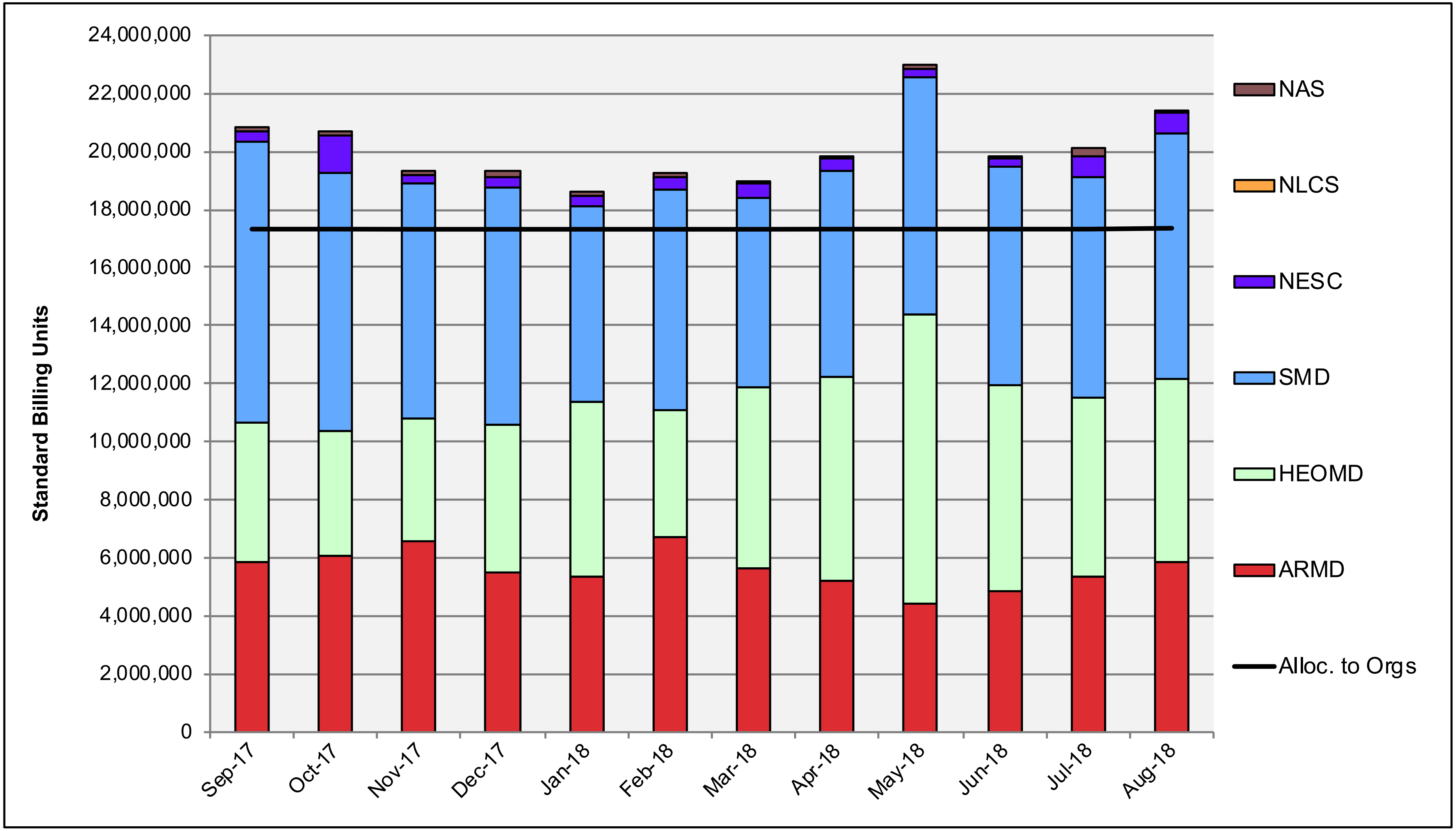
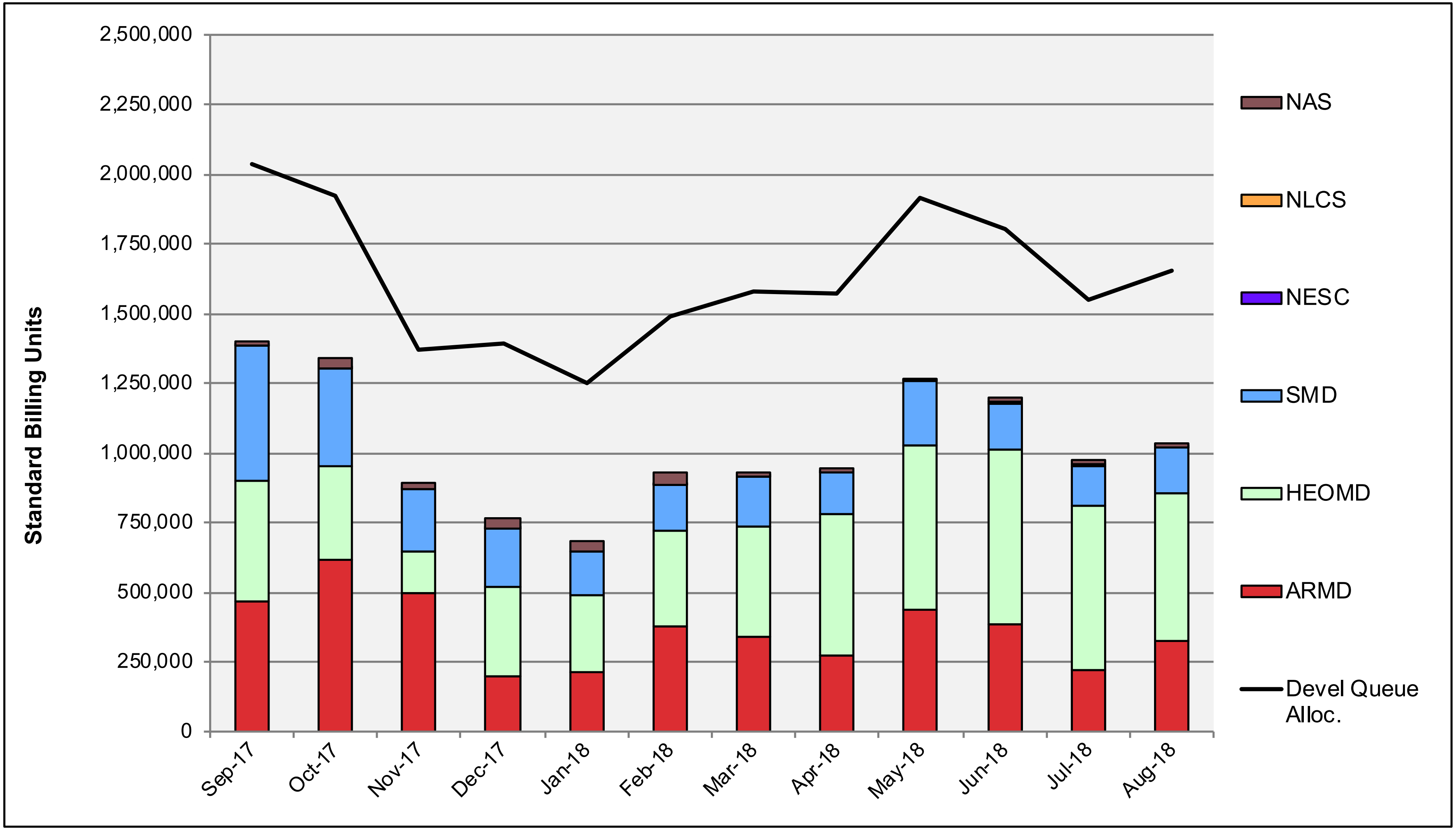


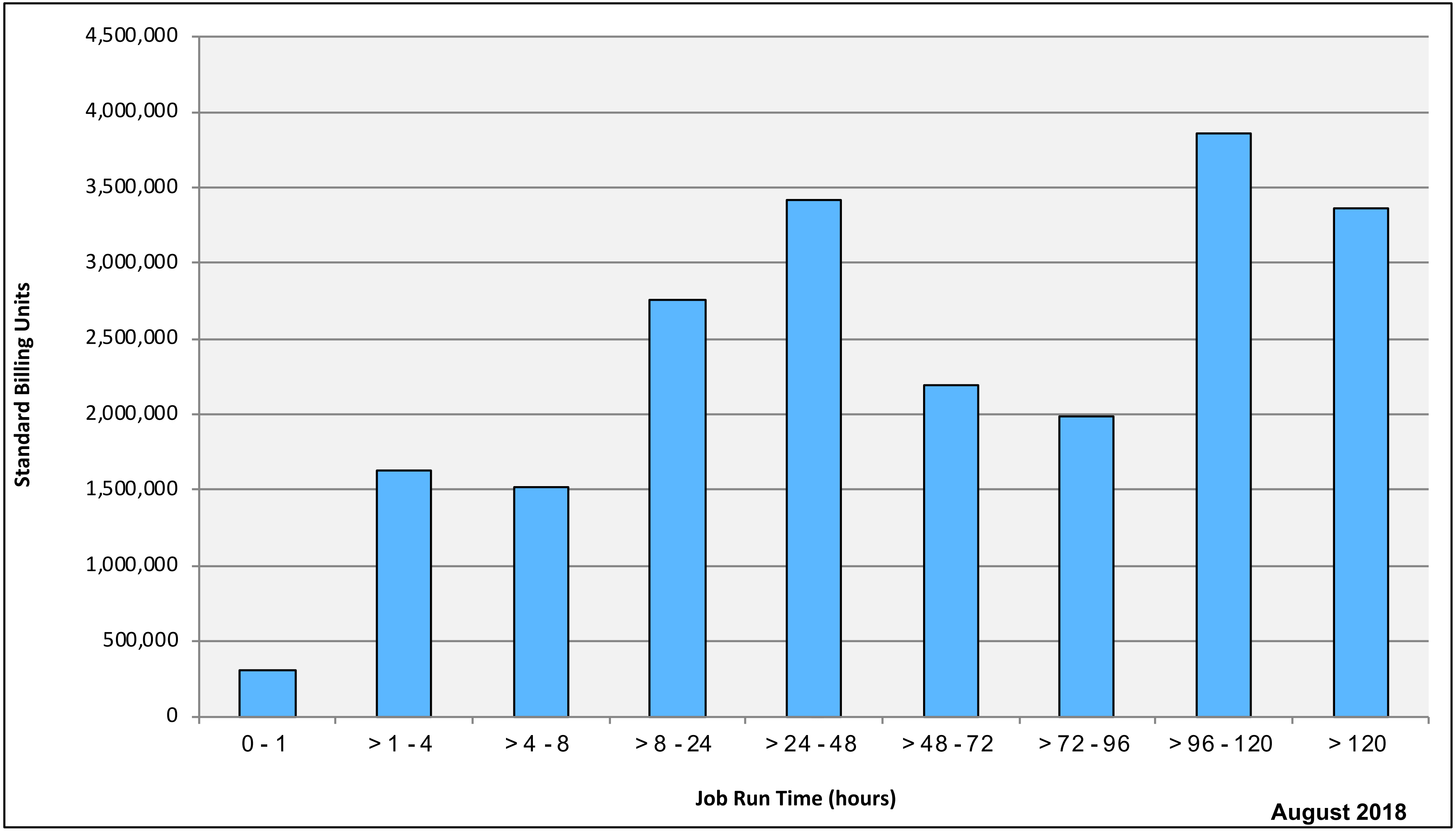
Pleiades: SBUs Reported, Normalized to 30-Day Month



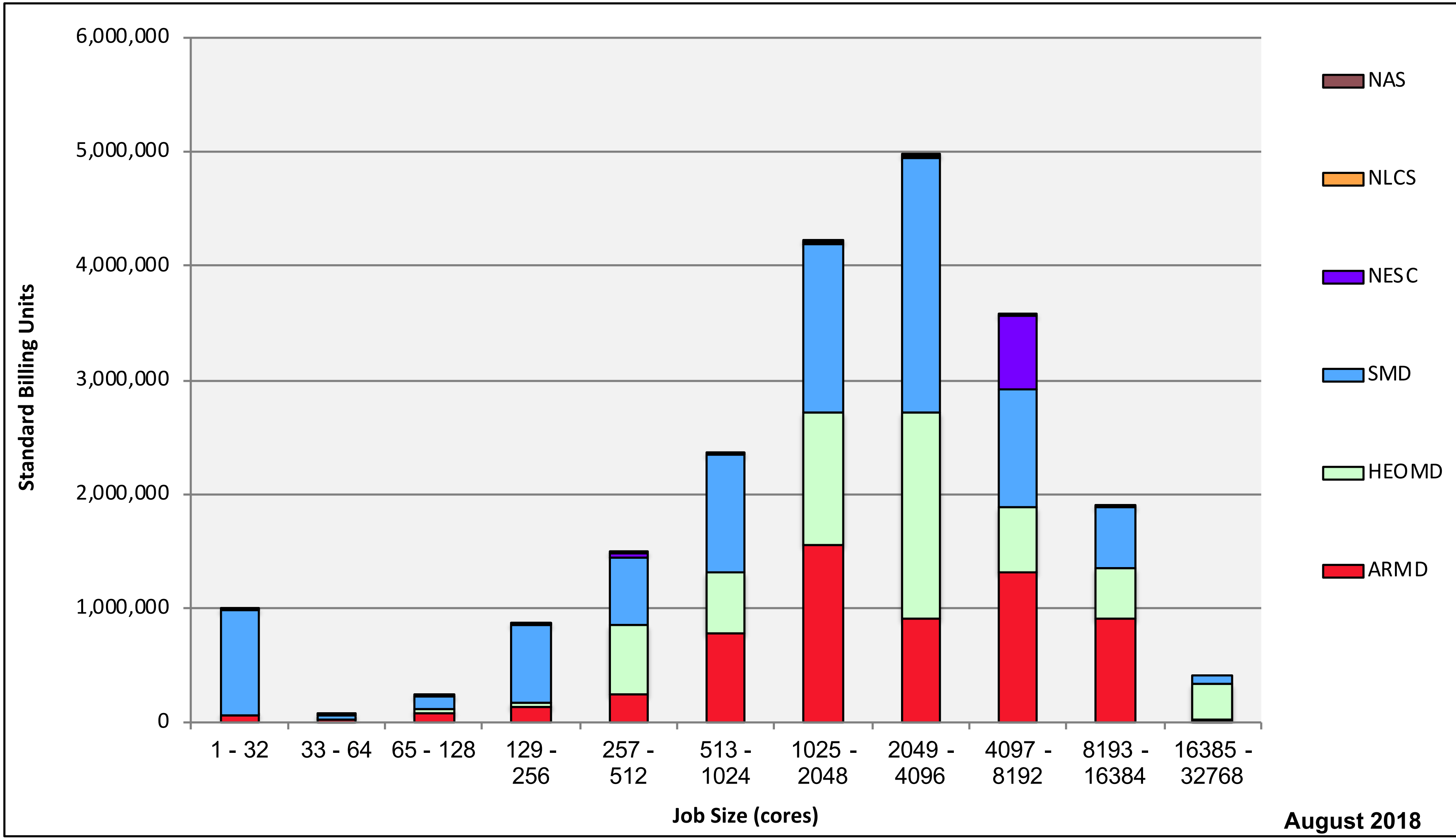
Pleiades: Devel Queue Utilization



Pleiades:
Monthly Utilization by Job Length



Pleiades: Monthly Utilization by Size and Mission



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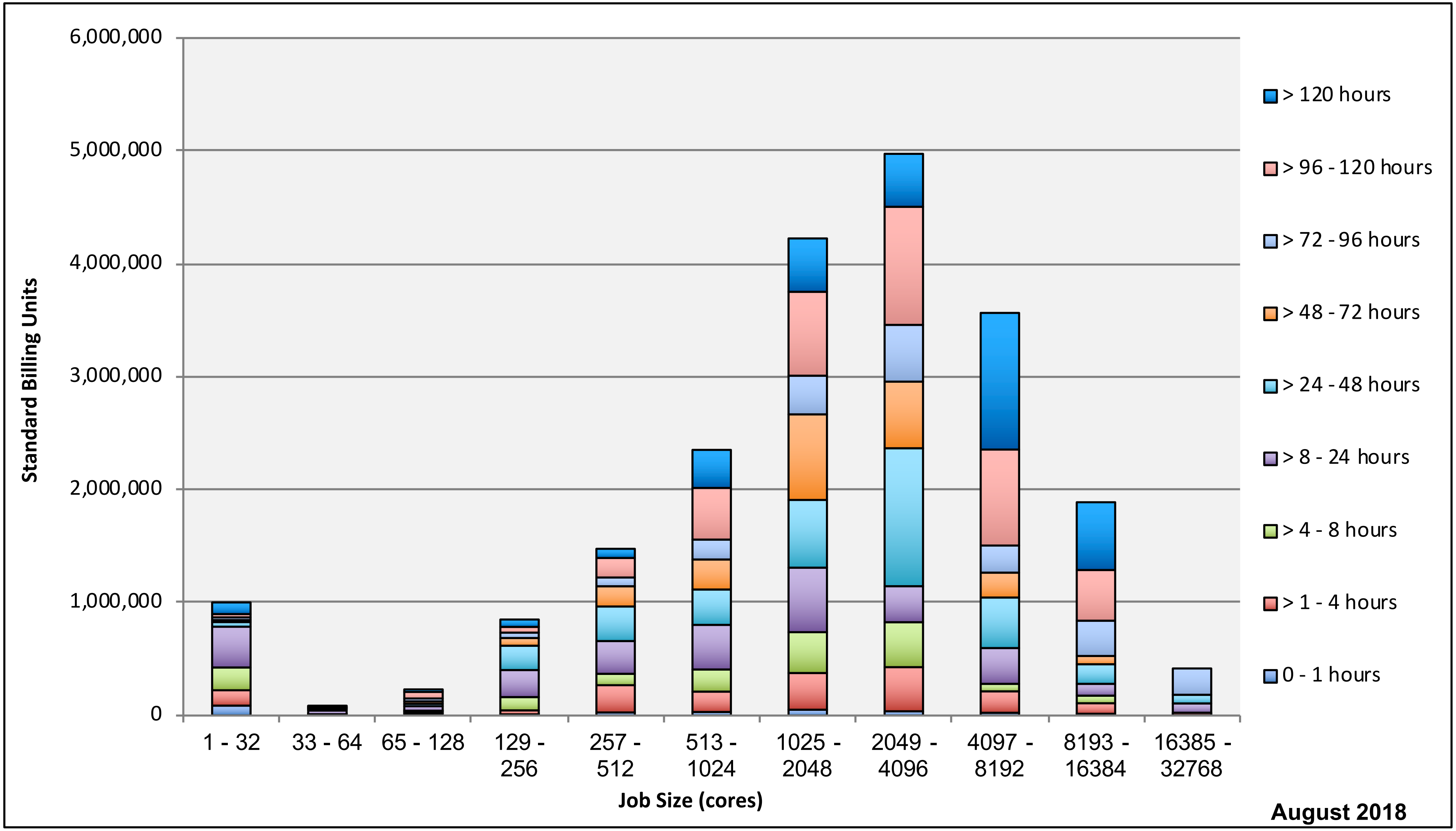
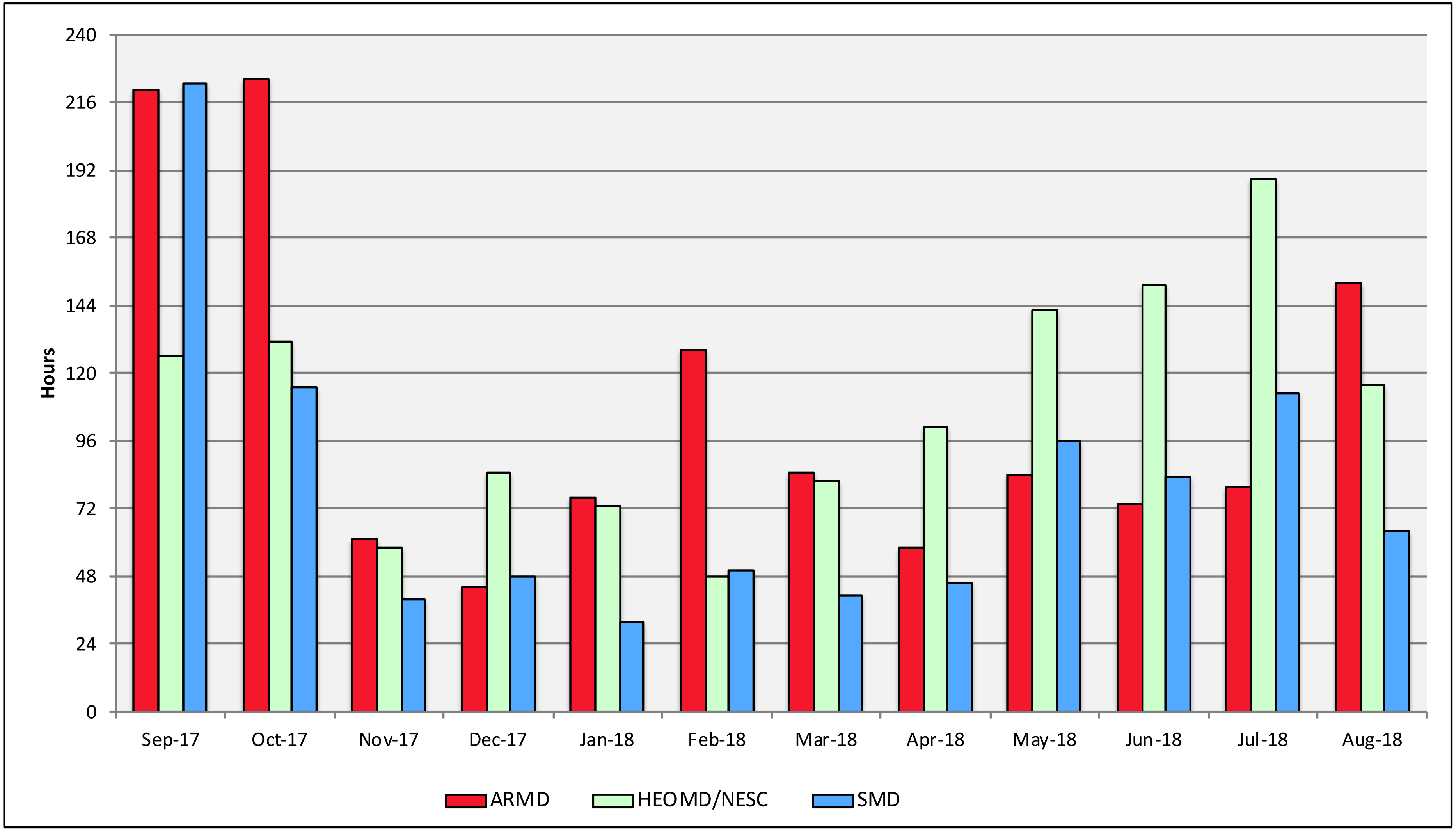
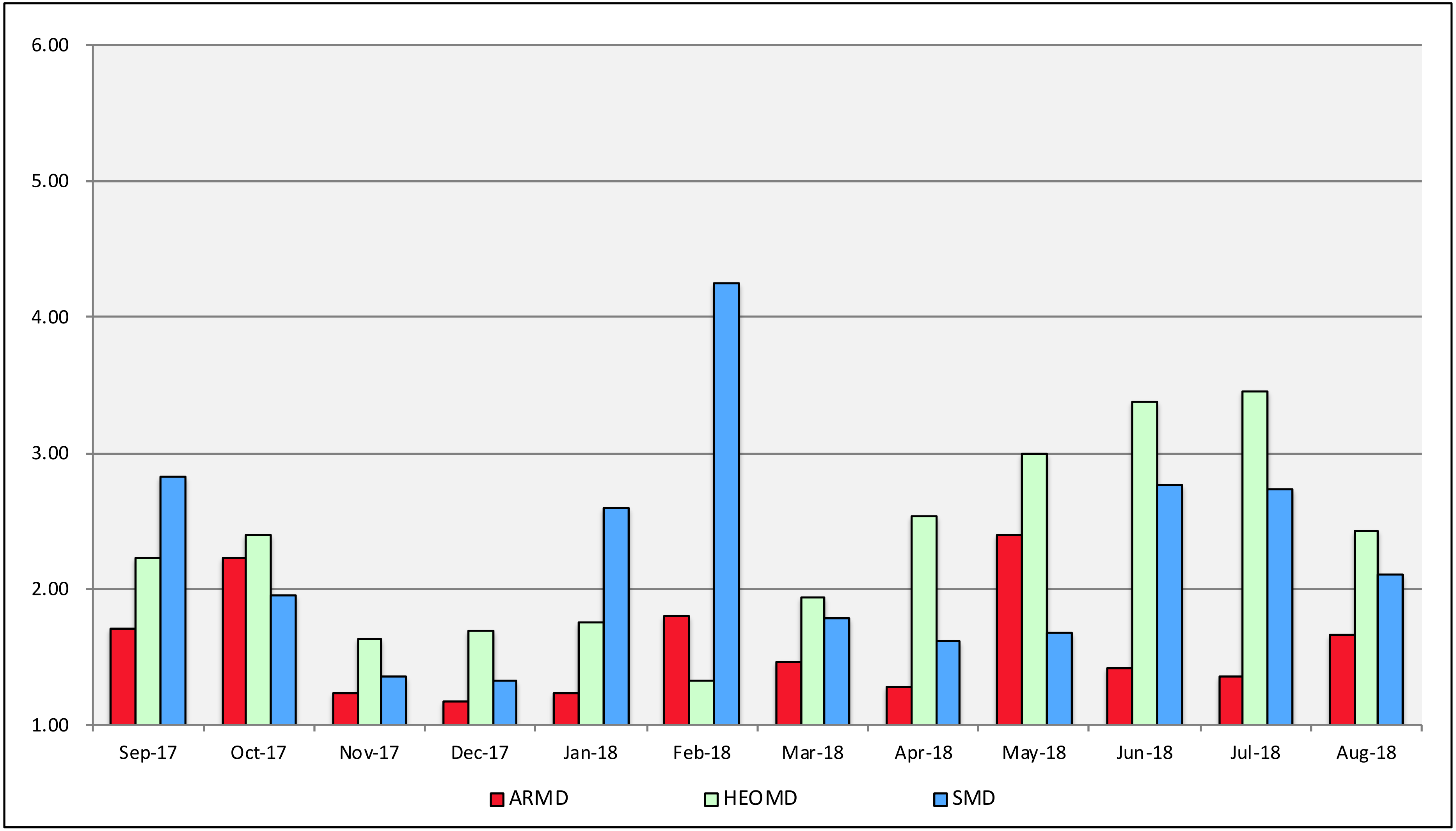


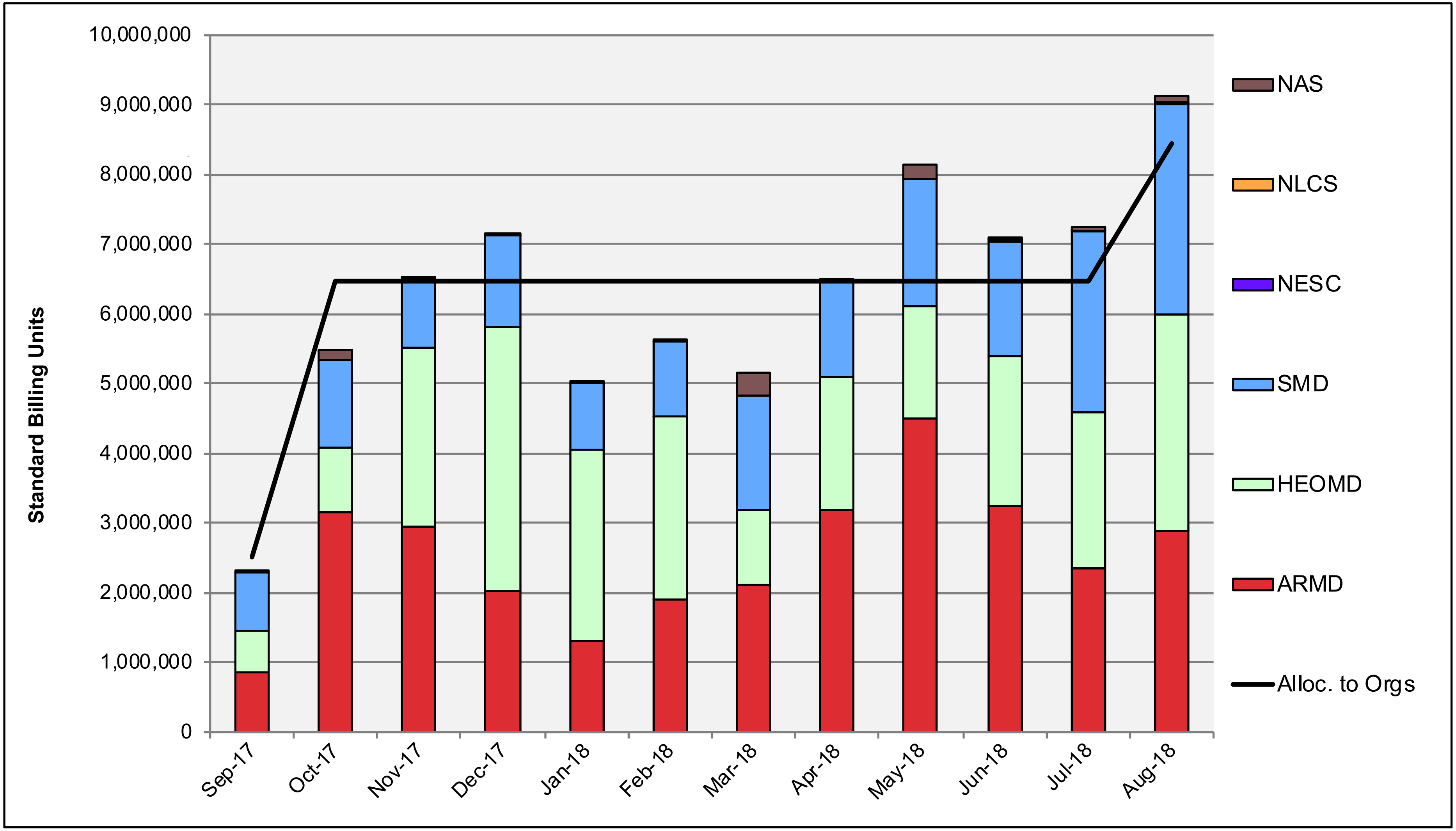
Pleiades: Average Time to Clear All Jobs



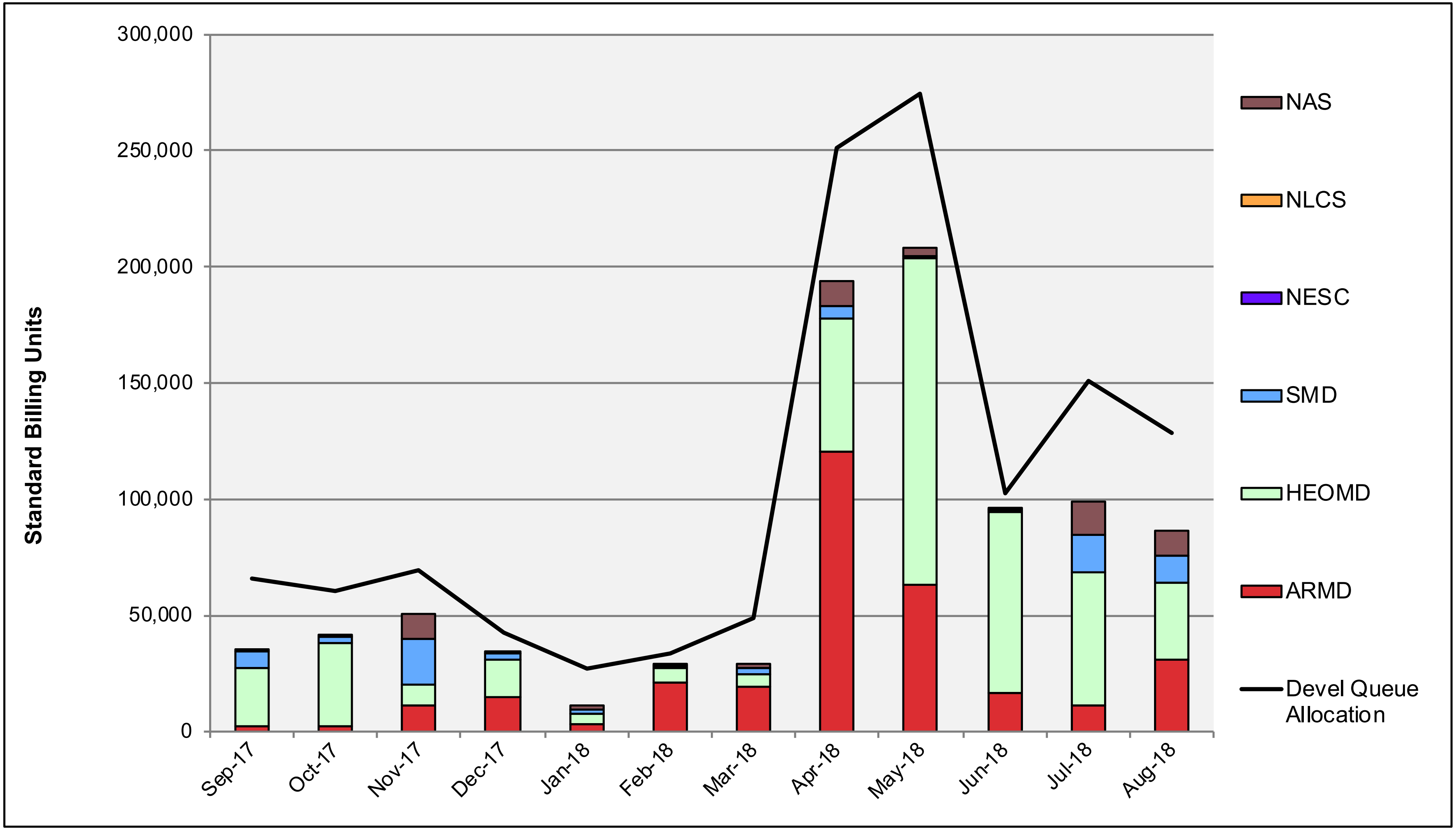
Pleiades: Average Expansion Factor



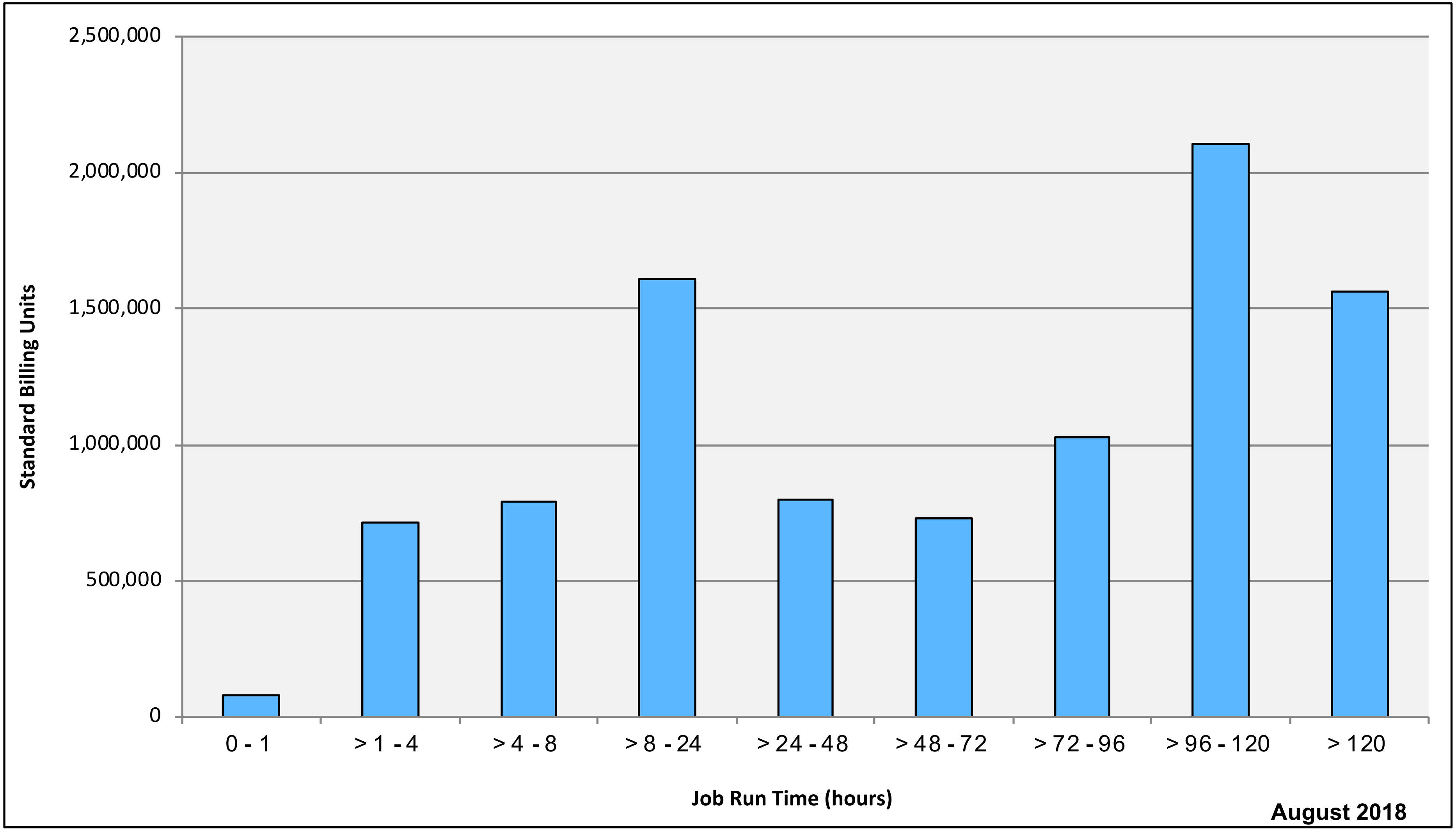
Electra: SBUs Reported, Normalized to 30-Day Month



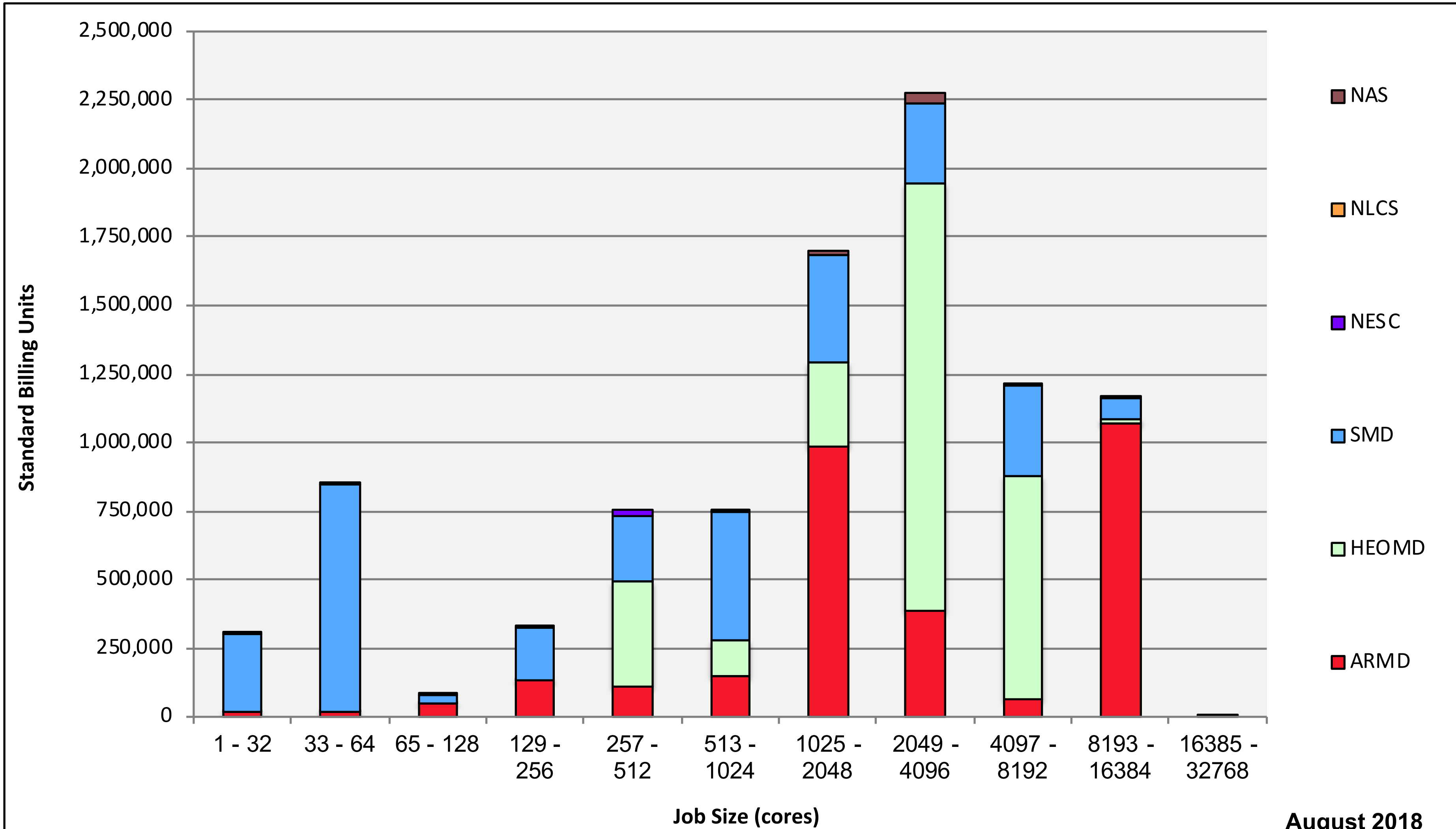
Electra: Devel Queue Utilization



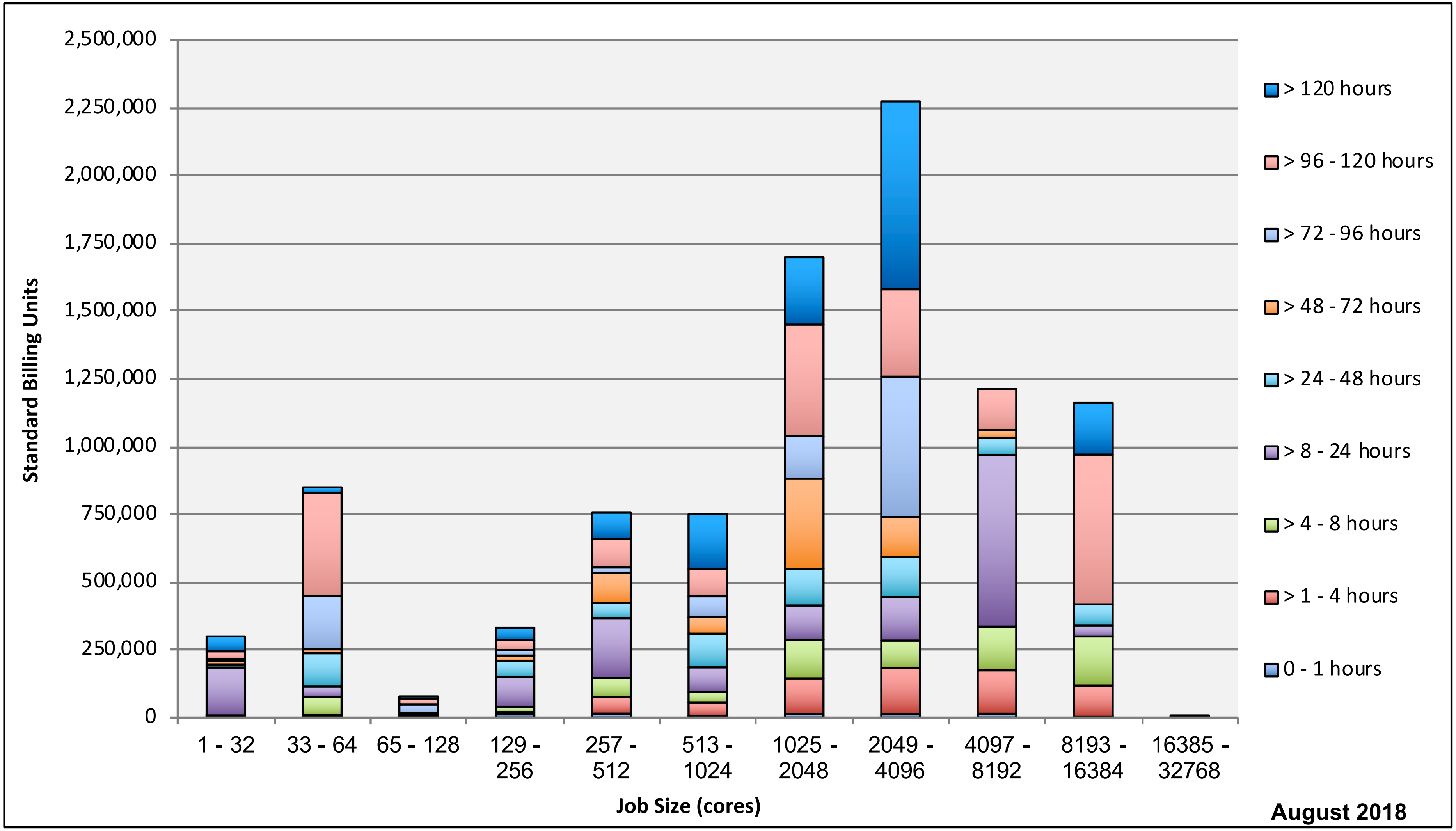
Electra: Monthly Utilization by Job Length



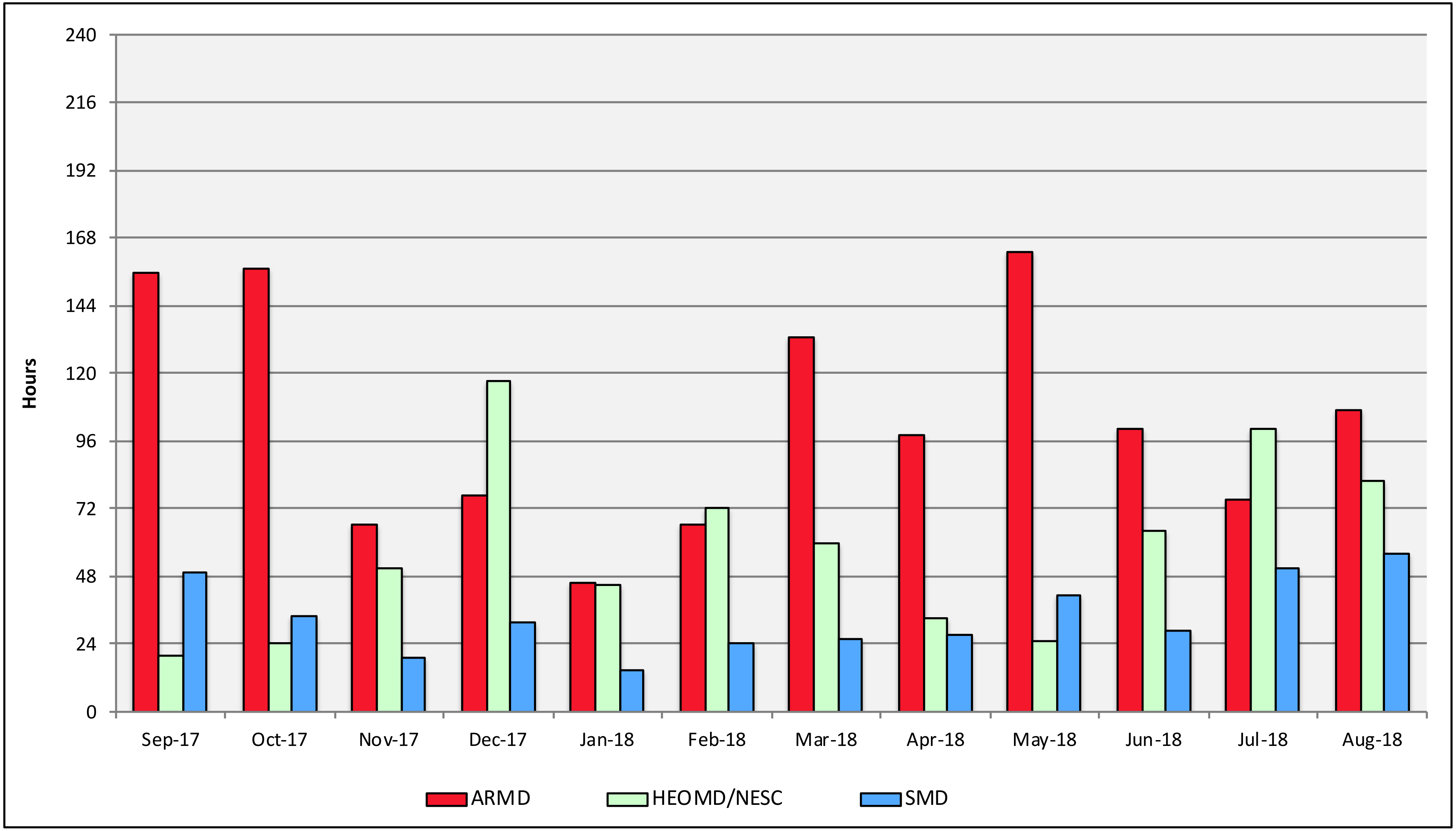
Electra: Monthly Utilization by Size and Mission



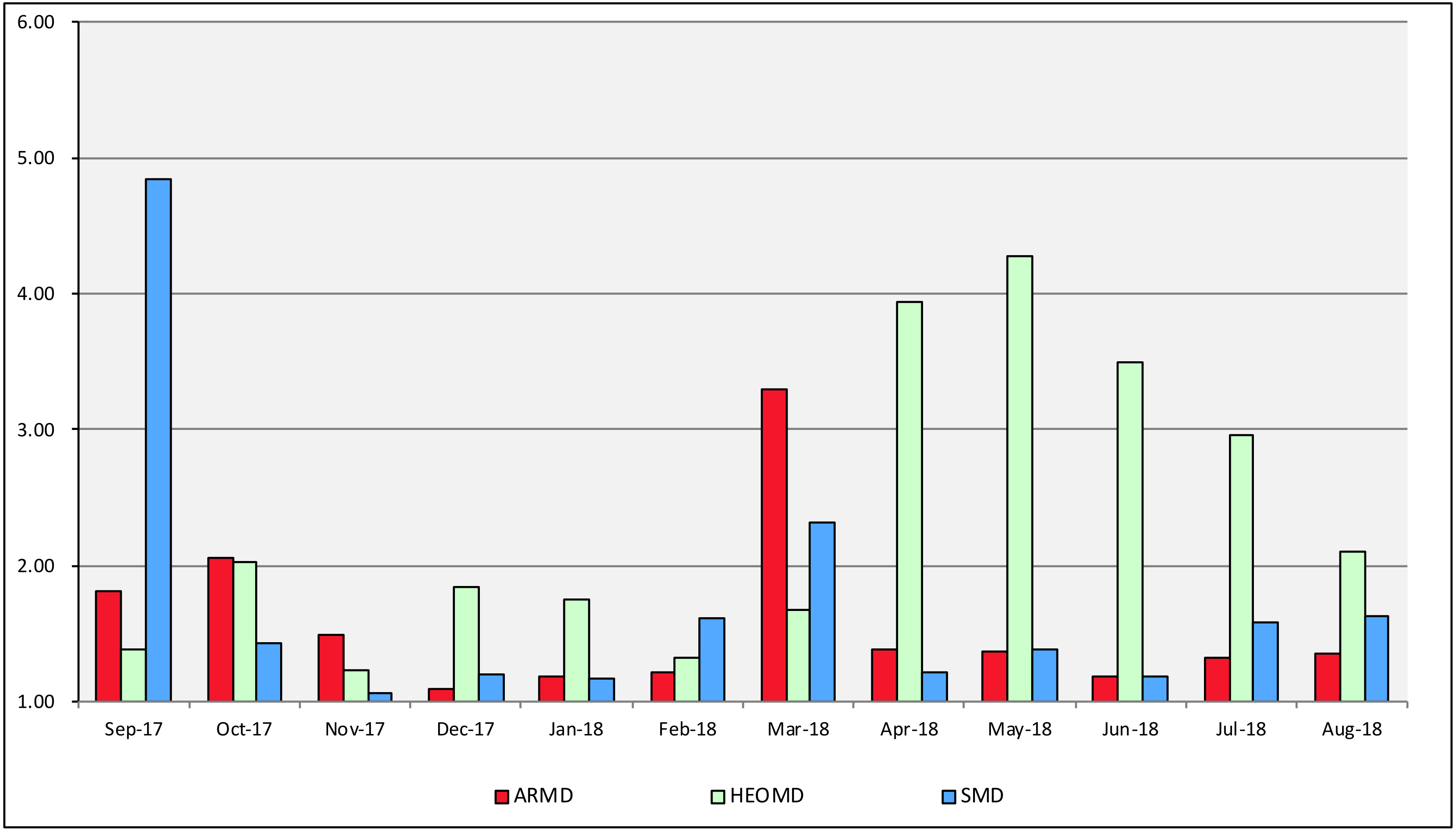
Electra:
Monthly Utilization by Size and Length



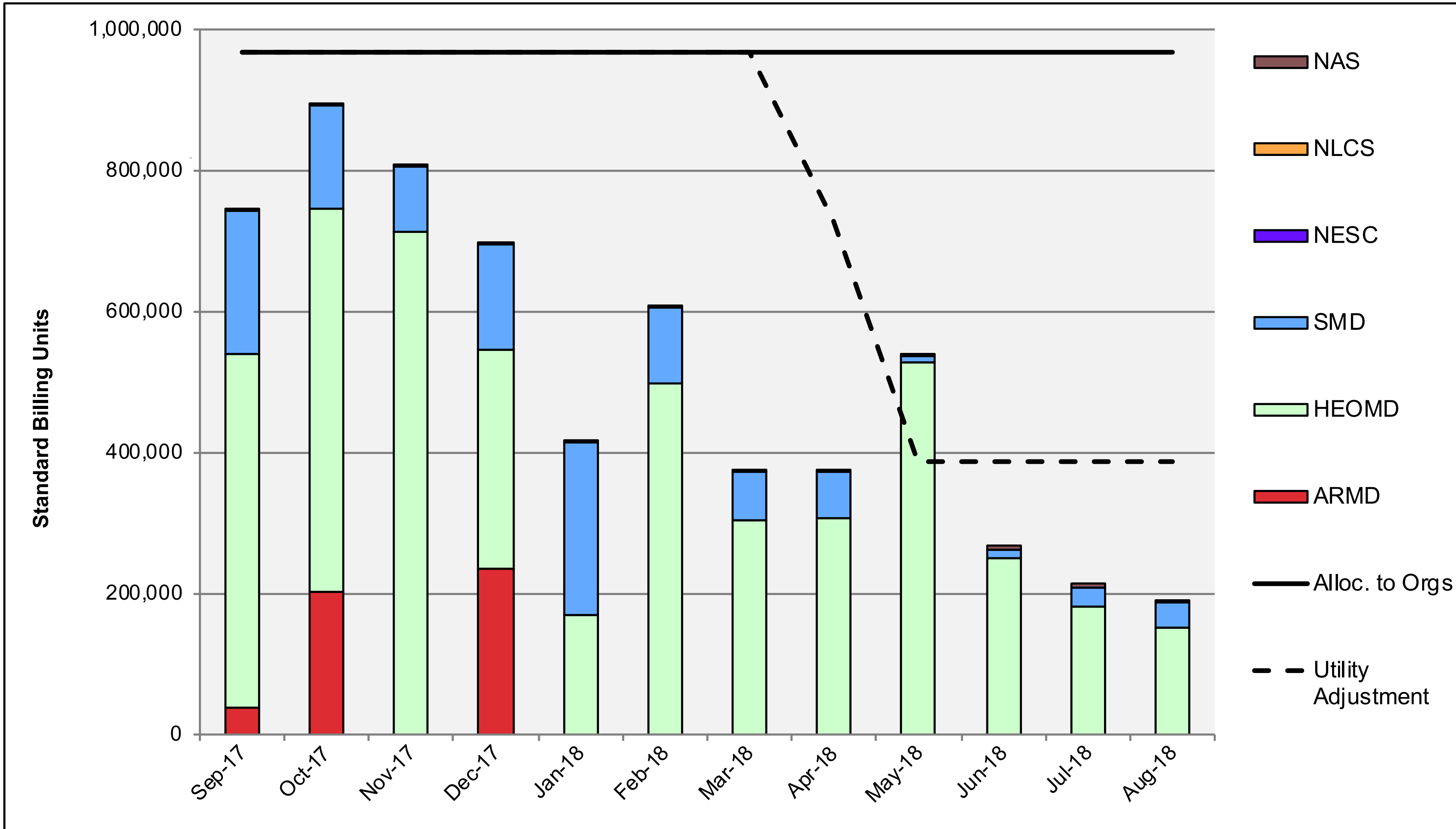
Electra:
Average Time to Clear All Jobs



Electra:
Average Expansion Factor

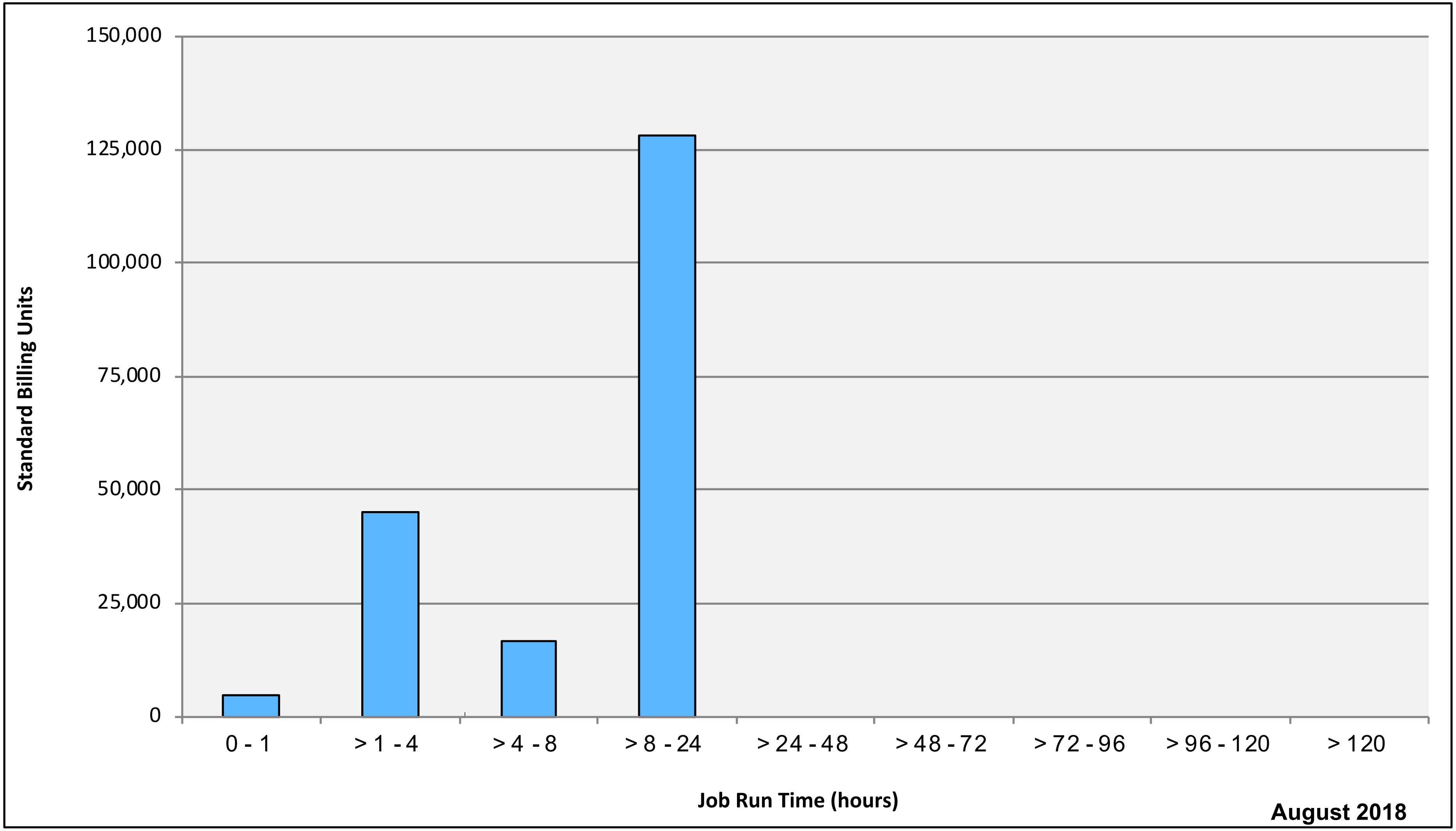


Merope:
SBUs Reported, Normalized to 30-Day Month

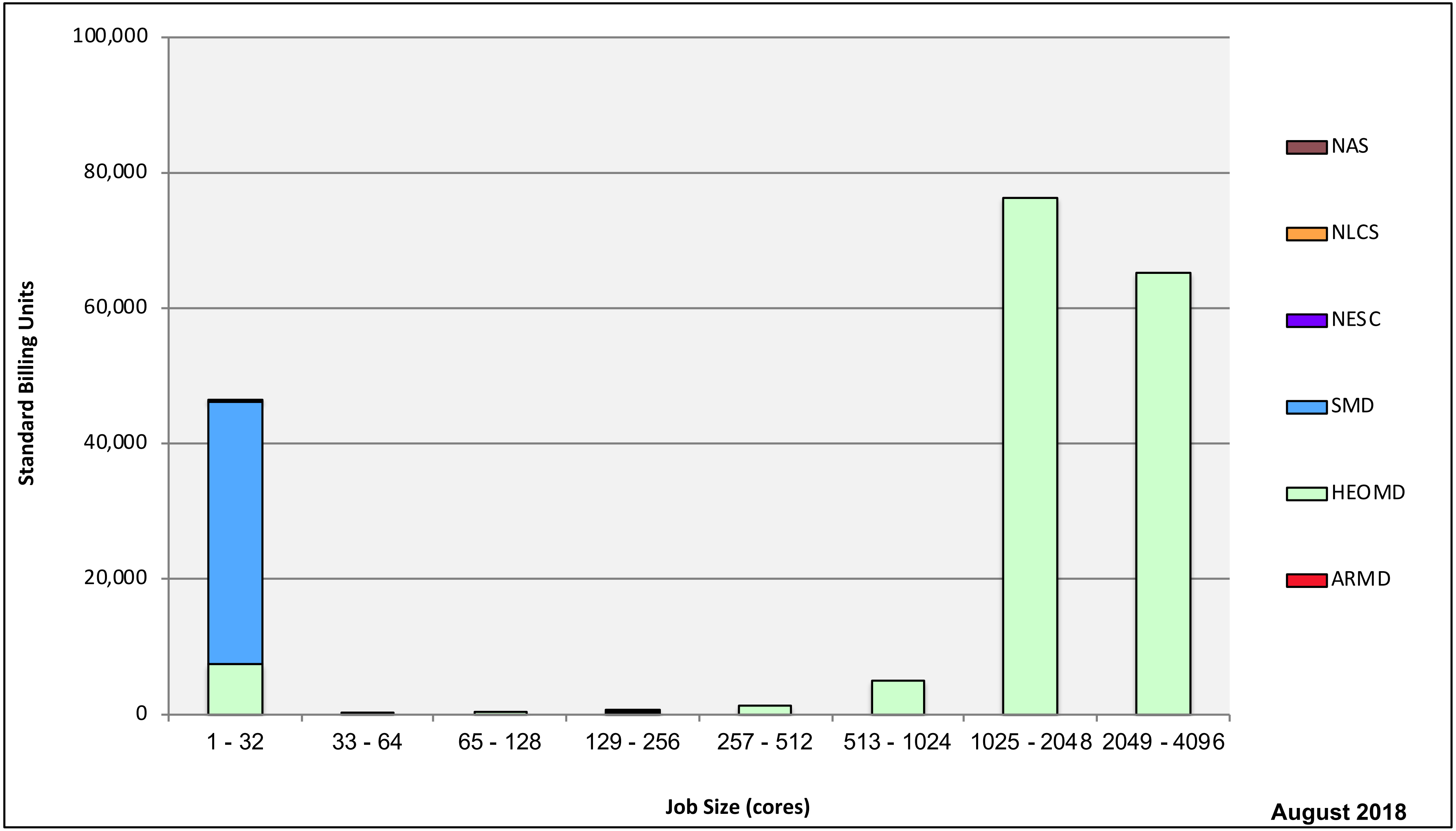


**** Repairs to multiple failures of N233A cooling system have taken a very long time, forcing HECC to turn off more than half the nodes***

Merope: Monthly Utilization by Job Length



Merope:
Monthly Utilization by Size and Mission



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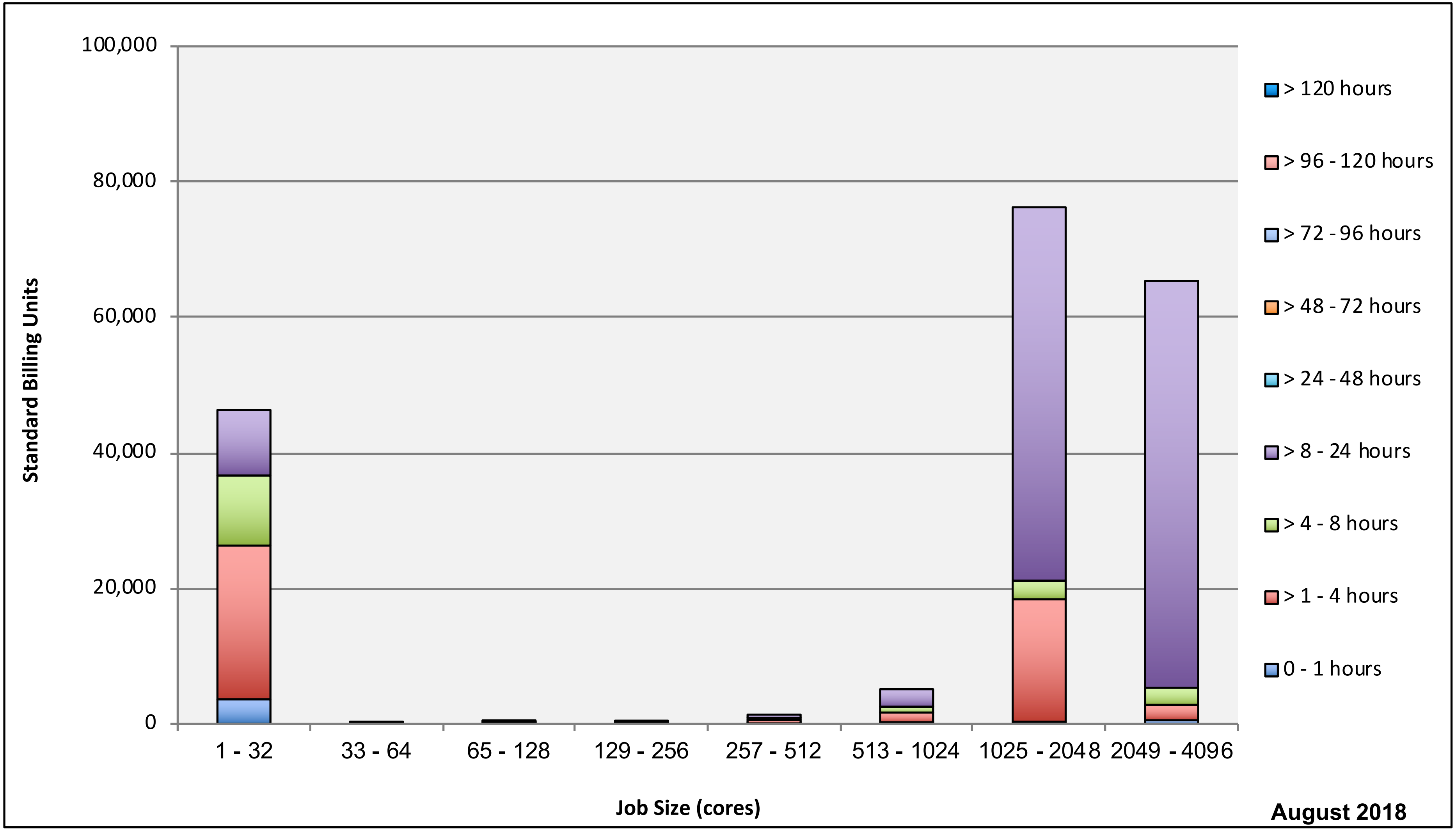
Monthly Utilization by Size and Length



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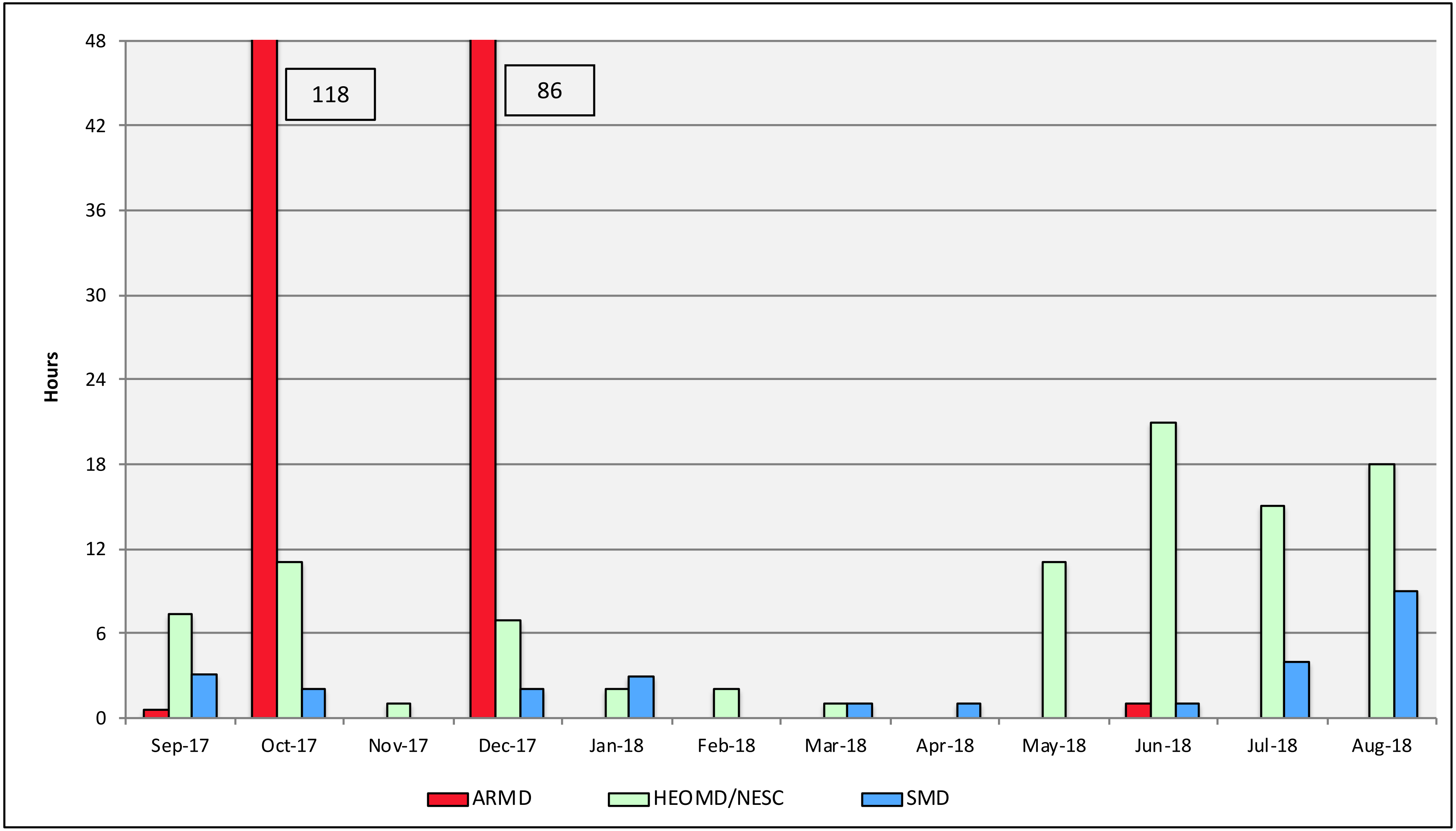
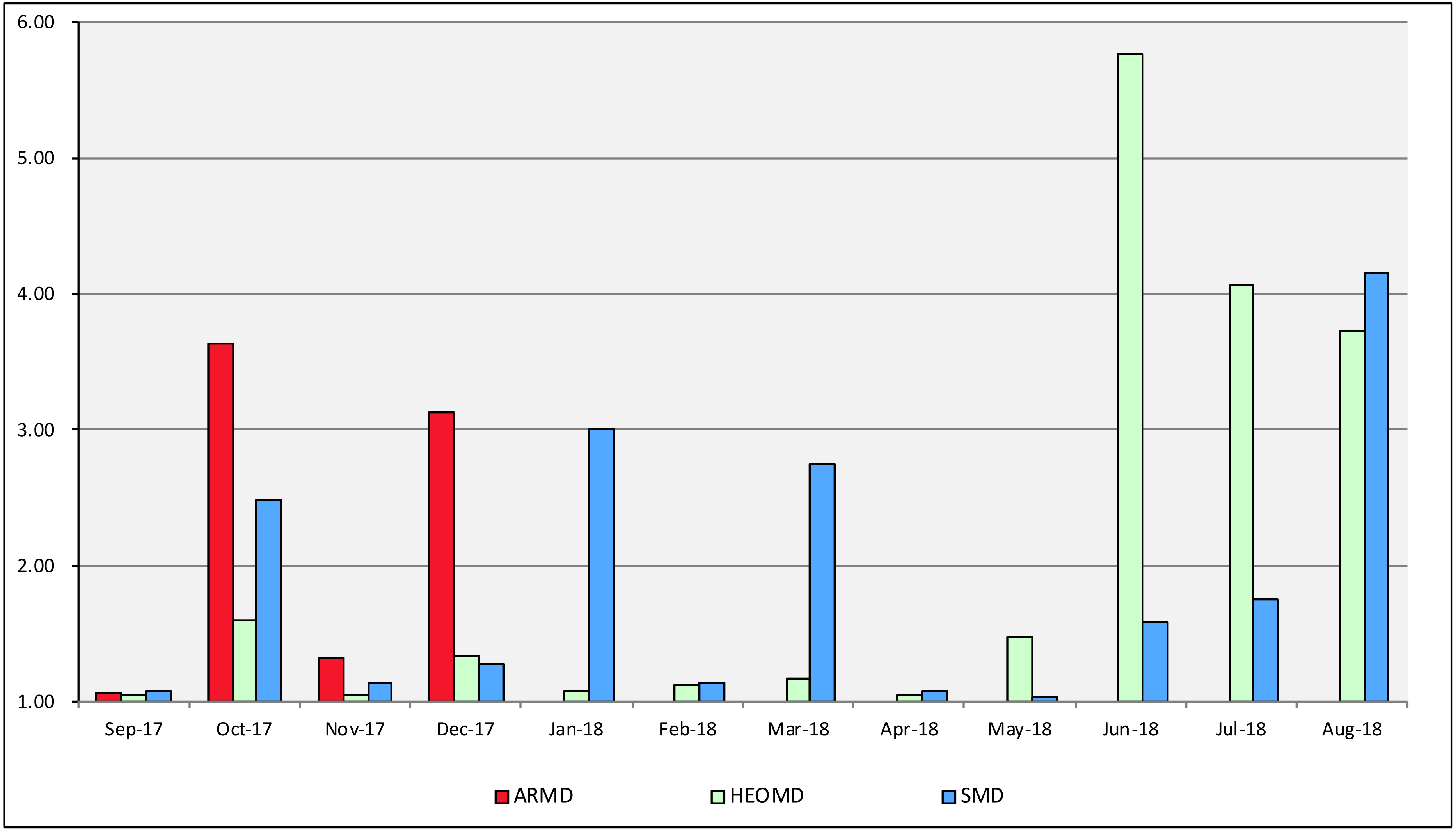
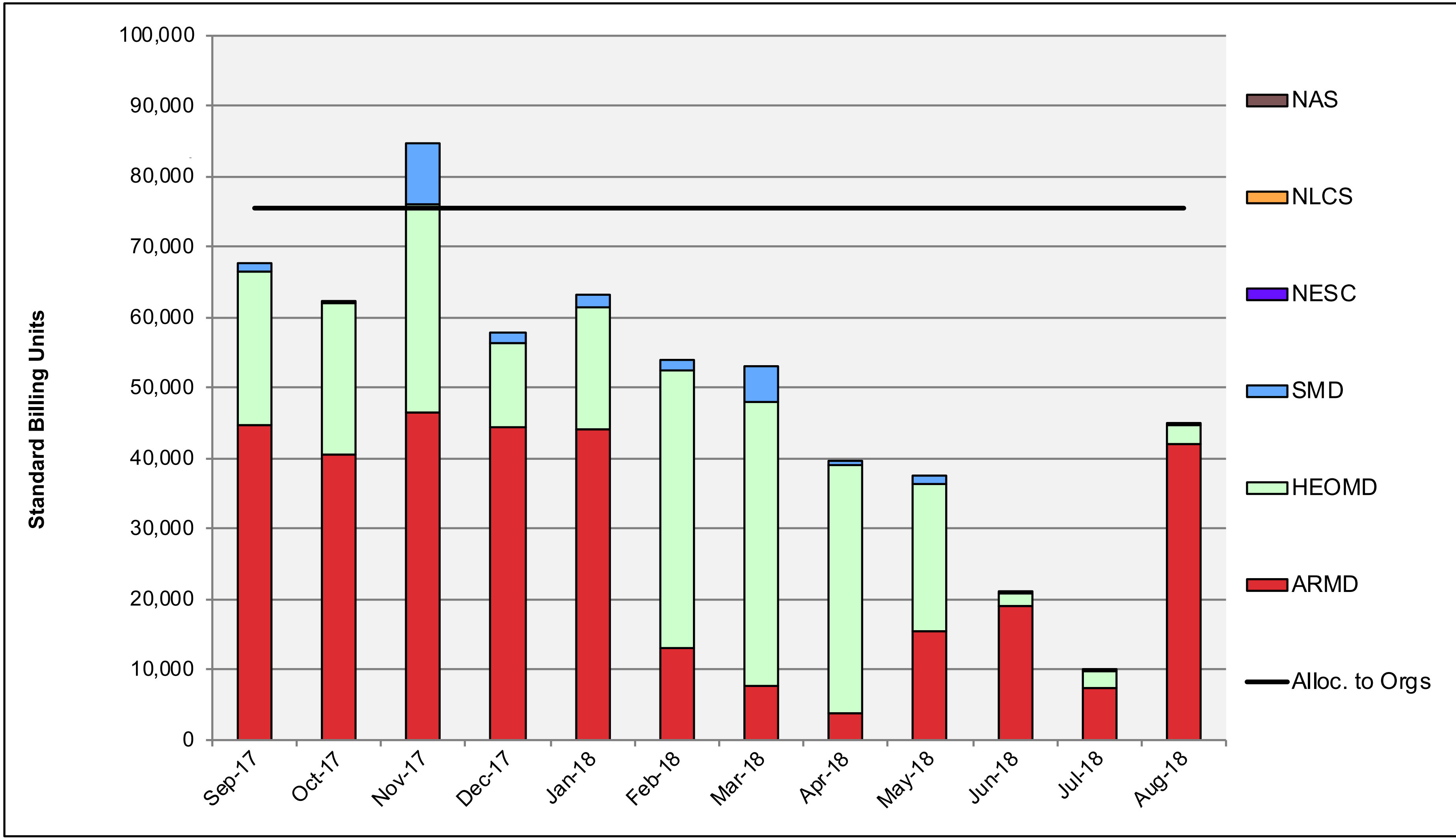


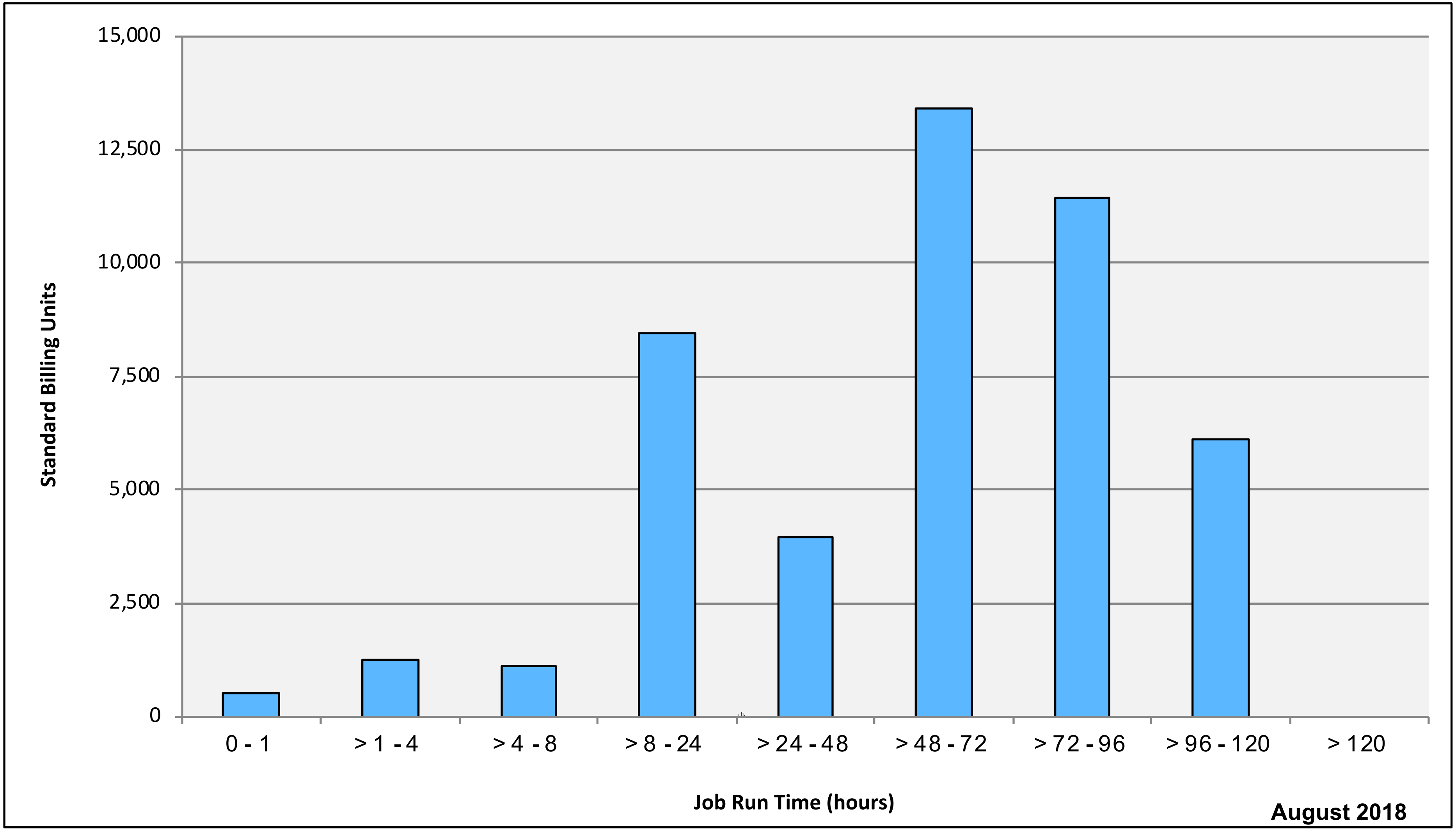
Merope: Average Expansion Factor



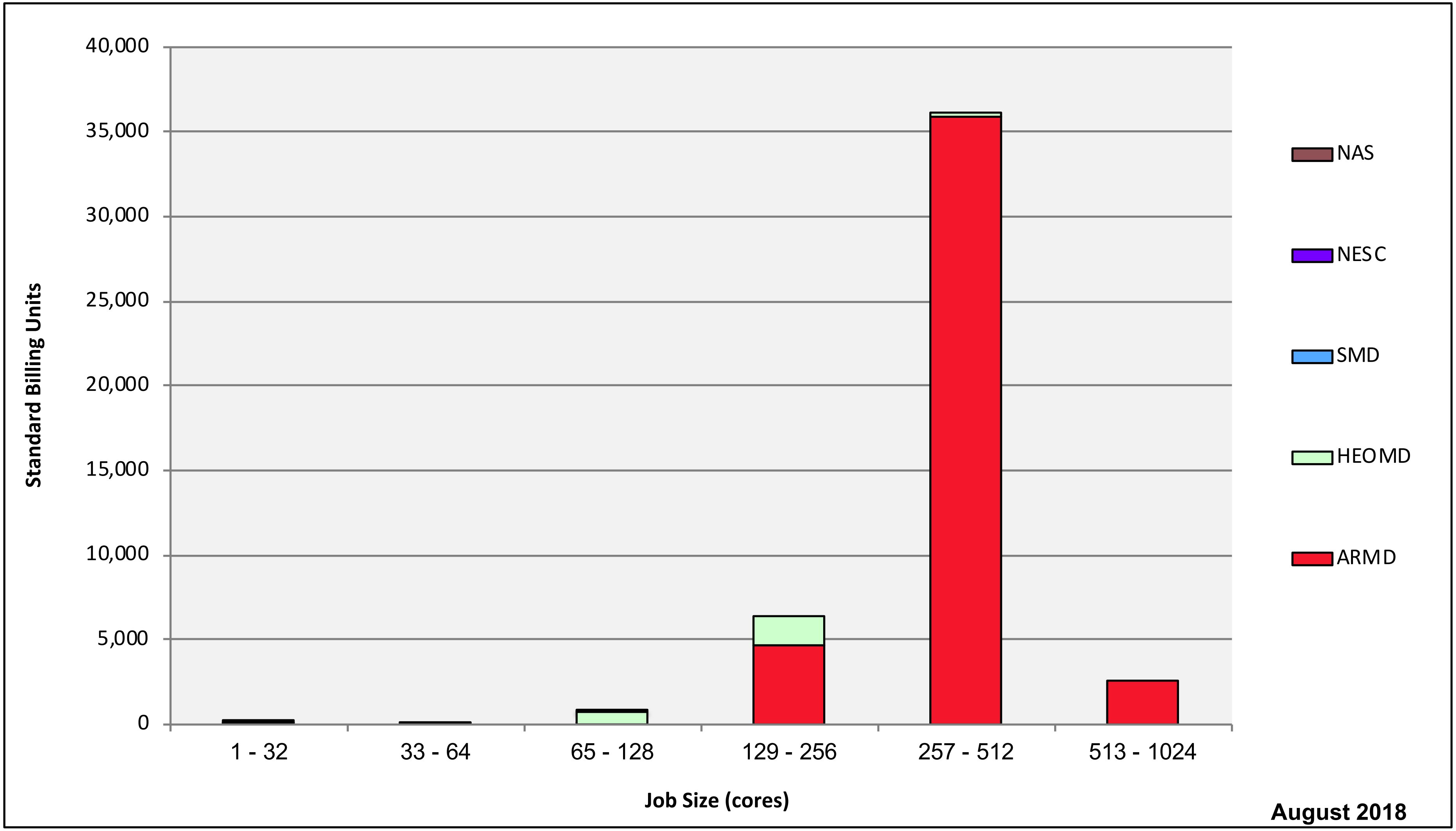
Endeavour: SBUs Reported, Normalized to 30-Day Month



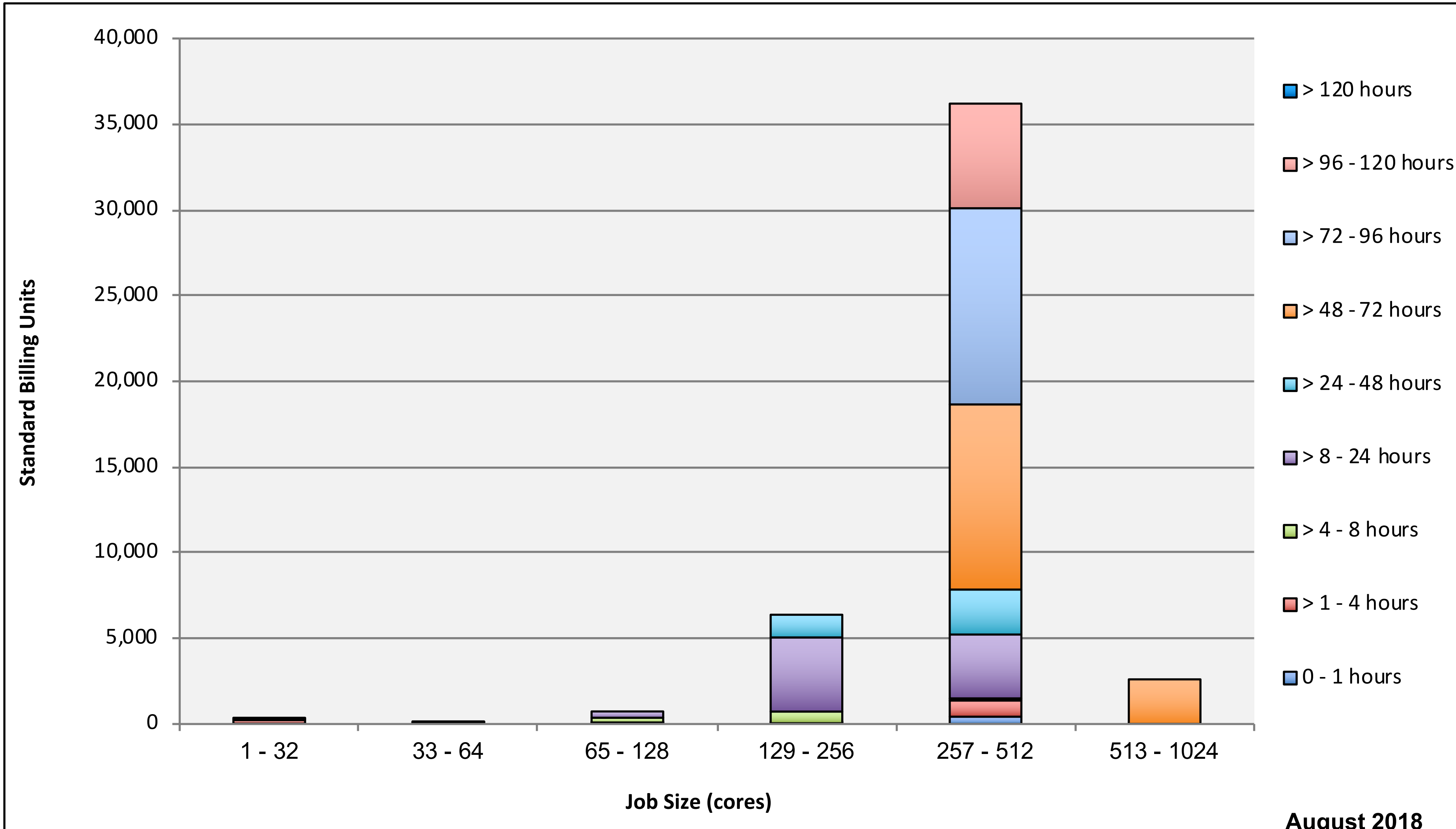
Endeavour: Monthly Utilization by Job Length



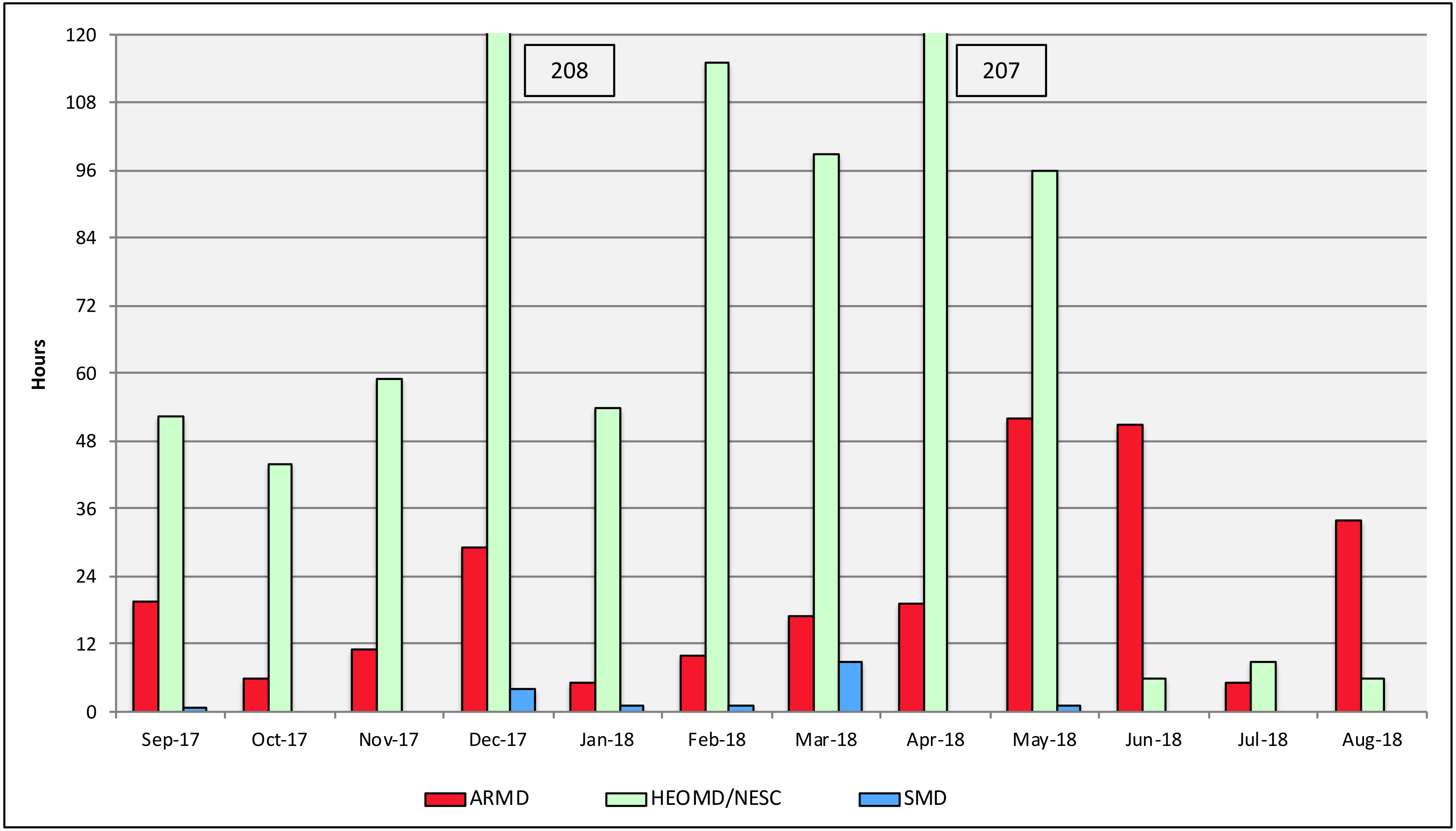
Endeavour: Monthly Utilization by Size and Mission



Endeavour: Monthly Utilization by Size and Length



Endeavour: Average Time to Clear All Jobs



Endeavour:
Average Expansion Factor